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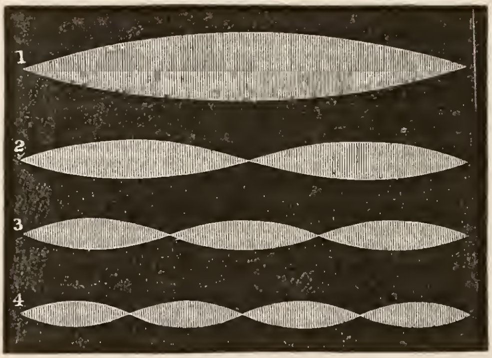
WAVE-ACTION IN NATURE.

THE waves upon water are always objects of pleasing interest. From the ripples of the pond to the billows of the ocean, their beauty and their sublimity are sources of perennial inspiration to the poet and the painter. But there is an invisible realm of air-waves of a far subtler and more wonderful order. The water-waves belong to the sensuous eye and to art, but the aërial pulsations belong to the eye of the imagination and to science, the great revelator of the super-sensuous harmonies of the universe. Water-waves afford an agreeable spectacle, and have little further concern for us; but the waves of air take hold of our highest life, for the multitudinous sounds of Nature by which we are soothed and exhilarated, all the delights of music, the pleasures of speech, and the sweet experiences of social intercourse, are made possible only through their agency. Besides, air-waves form one link in the chain of agencies by which we pass from the material to the spiritual world. The first is the capacity by which matter may be thrown into vibration; second, the properties of air by which it can take up the impulses of vibration in the form of waves; third, those properties of the mechanism of hearing by which it can take up the motion of air-pulses; and, fourth, those properties of nerves by which they can take up the tympanic vibrations and translate them into feeling or consciousness. How the last step is effected we do not know, but many of the preliminary conditions to it are understood, and to some of these we ask the reader's attention.

All sound begins in those collisions and attritions among material things by which their parts are thrown into tremors. These are almost as various in quality as the properties of material substances. The sounds we hear are but indices to the vibrations of bodies from which they proceed, and the multitude of such terms as splash, roar, ring, thud, crack, whiz, squeak, crash, illustrate the marvellous diversity of characters which material vibrations may take. In the production of noise, the thrills of matter are transient and irregular, but, when prolonged and regular, they give rise to musical sounds. Vibration depends upon elasticity, and bodies which are capable of the protracted and measured pulsations of music must, of course, be highly elastic. We have said that bodies vibrate differently, and this depends upon the nature, form, and magnitude of the mass in motion. The vibrations of bells differ with their sizes and the metals and alloys which compose them; while wooden and metallic tubes, strained strings, and stretched membranes, illustrate the same thing. If a tense wire be plucked aside, it executes lateral vibrations which differ with its varying length, strain, and density. It may vibrate as a whole (1), Fig. 1, while, by relaxing the tension, or by touching or *damping* it at different points, it may be made to break up into different systems of vibration as shown in (2), (3), (4), Fig. 1. The points of rest in such cases are called *nodes*. Rods and tubes of wood or glass may be made to vibrate *longitudinally* by rubbing them lengthwise with the rosined fingers or a damp cloth. Fig. 2 represents a glass tube, six feet long and two inches in diameter, which, by being vigorously rubbed in this way, was set into such violent vibration that it went to pieces.

Fig. 1.

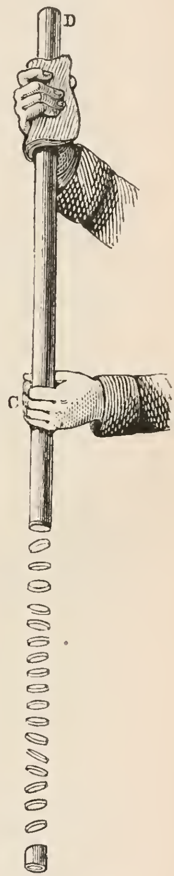


A String in Different Phases of Vibration.

If thin plates of glass or metal be clamped in the centre, and fine sand scattered over the surface, they may be set into vibration, and the sand will be tossed away from certain parts of the surface and collected in other parts, forming regular geometrical figures. The sand collects at the lines of rest, which are called *nodal lines*. Fig. 3 represents this experiment, the vibration being produced by a fiddle-bow, while the application of the fingers at different points determines the lines of rest and the geometrical figures. Fig. 4 represents a number of the beautiful patterns that were obtained by Chladni, who first drew attention to this interesting phenomenon.

Now, in order that all these multifarious and diversified tremblings of natural objects may be brought into relation with animate creatures, a common medium of communication is necessary. The air around us is such a medium. It possesses the marvellous power of taking up the numberless and ever-varying thrills of material objects, and conveying them through space with all their peculiarities. The sensitiveness of the air (if we may so speak) to the faintest tremors in material objects, and its power of transmitting their individual qualities, are most wonderful. It drinks up the infinitesimal motions of things, and diffuses them swiftly, simultaneously, and in countless myriads in all directions around.

FIG. 2.



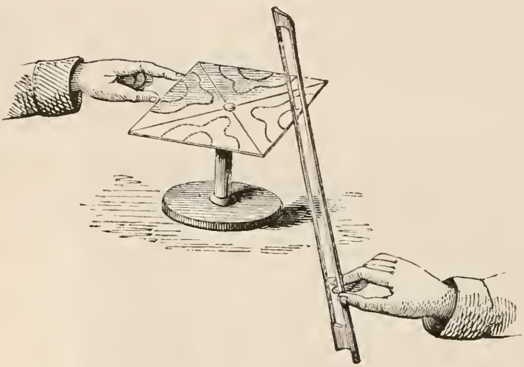
TUBE FRACTURED BY VIBRATION.

That air is the medium of sound is proved by the fact that, when vibrations occur in space void of air, the silence is not broken. If a bell suspended by a string in a vacuum be struck, nothing is heard, although, if it is in contact with the jar, the vibrations are communicated to the outer air, and sounds produced. That air transmits the kind of motion that it receives is also proved by the fact that it will take up vibrations at one point and communicate them to a distant object that is capable of vibrating in the same way.

The velocity of impulses in the air which produce sound has been well established, and all kinds of shocks—the firing of a gun, notes of a musical instrument, or the voice, whether high or low, harsh or soft—all move at the same rate. The velocity is not affected by changes in atmospheric pressure or moisture, or by rain or snow, but it is affected by wind and by temperature. The speed of sound is 1,090 feet per second at the freezing-point, and increases about one foot per second for each degree of ascent on the Fahrenheit scale. It, therefore, takes longer to hear in winter than in summer. In many parts of the country the change of temperature is so great that the velocity of sound will vary more than 100 feet a second in the different seasons. Sound moves in air with about the speed of a cannon-ball, and at a rate ten times greater than the swiftest motion of air in a hurricane. The sound produced in the open air tends to move in all directions with equal speed, but this tendency may be disturbed by various conditions. If the whole mass of air is moving in one direction, sound will travel faster with it than against it. In still air the sound of a musket-shot will be heard farthest in the direction of the impulse. Experiments have shown that a person speaking in the open air can be heard about equally well at a distance of 100 feet in front, 75 feet on each side, and 30 feet behind. When an obstacle checks a sound in one direction it can be heard farther in others, because, as a given amount of force produces a given amount of motion, if the motion is arrested in some directions, it is increased in others.

We have now seen that air is the common vehicle of sound, and that the sound-impulse moves in all directions at a high speed. But what is it that actually moves? The particles of air are certainly not shot from the vibrating body to the ear, for then we should live in the midst of storms ten times more violent than tropical cyclones. The wonderful elastic properties of gases here come into play. The vibrations of bodies produce waves or pulses in the air. It is the same in effect as with water-waves. When we throw a stone into a quiet pool, the ripples chase each other in circles to the shore, but the water itself

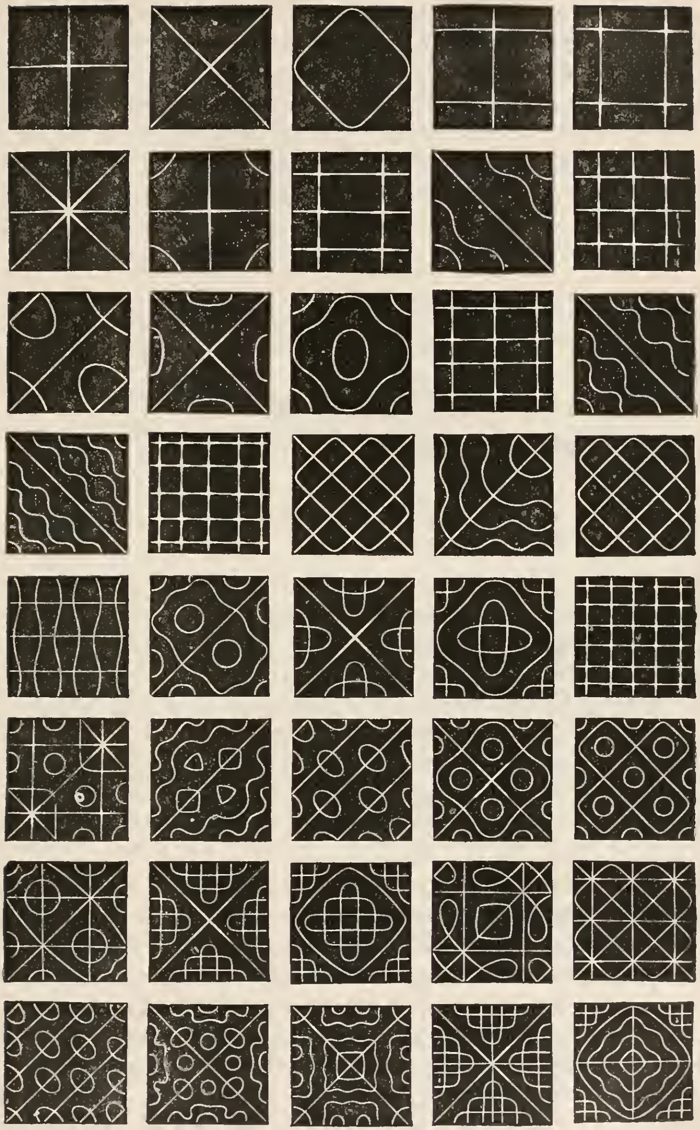
Fig. 3.



Vibrations of a Clamped Plate.

does not move forward. The floating straw is not borne along, but merely rises and falls in its place, and so the particles of water only oscillate up and down in circles, and, communicating their motion to the adjacent particles, there is an outward transference of force by wave-action, and the water-particles move up and down while the wave moves forward. Air-waves exemplify the same principle, but in a different way. A vibrating body throws the contiguous air into movement, and produces the wave. But the air-particles oscillate backward and forward or in the same direction as the advancing wave. The oscillations in water are *transversal;* in air, they are said to be *longitudinal.* The mode of movement may be rudely illustrated by a row of glass balls such as are employed in the game of "Solitaire." If a dozen of them are placed in a groove in contact (Fig. 5), and one of them be withdrawn with the hand and lightly struck against its neighbor, the motion imparted to the first ball is delivered up to the second,

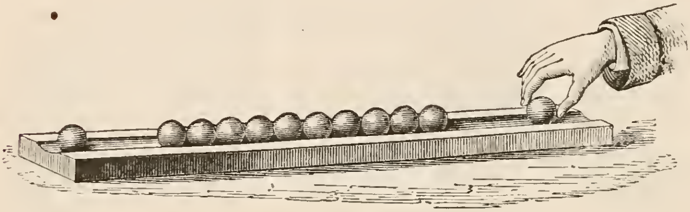
FIG. 4.



CHLADNI'S FIGURES OF VIBRATING PLATES.

that to the third, and so on, while the last ball only of the row flies away. The balls being elastic, the first one struck is not pushed from its position, but is slightly compressed, and then expanding it compresses the second, which, again expanding, compresses the third; and so there is propagated a series of compressions and expansions through the row. In a similar way the action of a vibrating body upon the air is to produce a series of condensations and rarefactions which are sent successively forward through the atmosphere, and each condensation, with its associated rarefaction, constitutes a sonorous wave. This is illustrated in Fig. 6, where A B represents a tuning-fork in vibration. As the prong, *a*, strikes against the air, its particles are driven together or condensed in front of it, and, as the prong retreats, it leaves a partial vacuum behind. Each vibration thus generates a wave.

Fig. 5.



Propagation of Impulses through Balls.

The oscillations of the air-particles are communicated to the adjacent particles, and the impulse is sent forward. In Fig. 6, *b c d* represent the condensations, and *b′ c′ d′* the accompanying rarefactions in the propagation of impulses through the air.

If, now, we imagine these dark and light spaces prolonged in circles round the tuning-fork, we shall have an idea of the way sound moves in all directions. We are to conceive of air-waves as bubbles or spheres, which rapidly expand from the point of vibration, and chase each other outward with the speed of musket-balls.

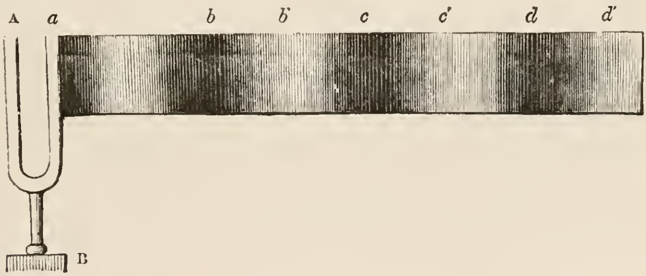
We have said that the waves of sound take place in an invisible realm, yet it is in the power of science to bring them into view. This triumph of experiment is due to a German named Toepler. Prof. Rood has given an account of it in his admirable lecture on the "Mysteries of the Voice and Ear." It depends upon the principle that, "when light which is travelling through the atmosphere meets with a denser or rarer layer, it is usually turned a little out of its straight path—a very little—but enough, sometimes, to render the layer actually visible, if proper optical means are employed." But, how is a wave to be made visible, if it moves with the speed of a cannon-ball, "which goes so fast we cannot see it?" It is by getting a glimpse of it so quickly that it has no time to move, and appears as if at rest. Those who have seen a railway-train at high speed illuminated by a flash of lightning, will remember that it appeared as if standing still. So, if a cannon-ball were passing through a darkened room, and could be illuminated by an electric flash, it would seem to be at rest in mid-air. By suitable arrangements, and the use of the electric spark, Prof.

Toepler caught the air-waves on the instant, and got a glimpse of their circular, and even their shaded aspect.

We have said that "the difference between noise and music is, that in noise the waves strike the ear irregularly, while in music they are regular, and so rapid as to blend together. Any sound which becomes continuous by rapid periodic strokes is said to be musical. "If a watch, for example, could be caused to tick with sufficient rapidity—say one hundred times a second—the ticks would lose their individuality, and blend to a musical tone. And, if the strokes of a pigeon's wings could be accomplished at the same rate, the progress of the bird through the air would be accompanied by music. In the humming-bird, the necessary rapidity is attained; and, when we pass on from birds to insects, where the vibrations are more rapid, we have a musical note as the ordinary accompaniment of the insect's flight."

Sounds vary in pitch, and the pitch depends upon the rate of vibration. The greater the number of vibrations in a second, the shorter and quicker are the waves, and the higher the tone. It has been determined, in various ways, exactly how many vibrations there are in

Fig. 6.

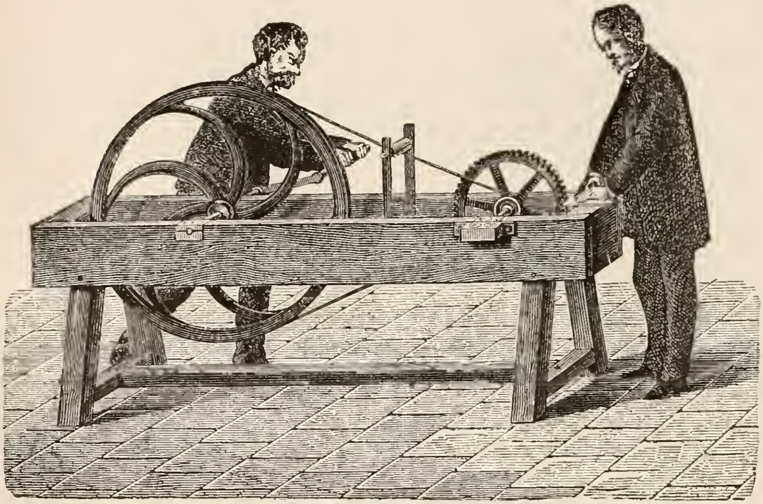


Constitution of Air-Waves

each musical note. Savart employed a toothed wheel, which could be set in motion at any desired rate of speed, and which had attached a small recording apparatus that gave the number of revolutions in a second. Fig. 7 represents the mechanism, and the mode of using it. While the wheel is in revolution, a thin visiting-card, or a piece of pasteboard, is held against its toothed edge. The card is bent a little by each tooth, as it goes by, and springs back to its first position as soon as it is released. When the wheel is turned slowly, there is heard only a succession of taps, distinctly separable one from another; but, as the rapidity of the rotations increases, the number of strokes increases also, and they soon unite to form a musical sound, while, exactly as the motion is accelerated, the sound rises in pitch. In this way it is possible to count the number of vibrations in producing every note in the musical scale.

The usual range of hearing lies between 16 vibrations in a second and about 38,000 vibrations per second. Starting with 16 vibrations per second, as the number is increased we have a series of rising musical notes, until the number is doubled, and an *octave* is produced with 32 vibrations per second. Increasing them from this point, the notes rise in pitch until they are again doubled, and we have the second octave with 64 vibrations per second. By thus ascending through 11 octaves, the number of vibrations reached would be 32,768 per second; but all the notes comprised within these limits cannot be employed in music. Tyndall states that the practical range of musical

Fig. 7.



Savart's Apparatus for numbering Vibrations.

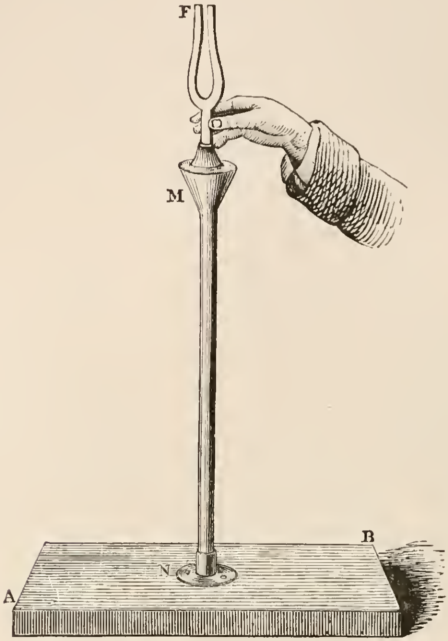
sounds is comprised between 40 and 4,000 vibrations per second, which amounts, in round numbers, to seven octaves. Helmholtz says that the deepest tone of orchestra instruments is the E of the double bass with $41\frac{1}{4}$ vibrations. The new pianos and organs generally go down to 33 vibrations. In height, the piano-forte reaches to 3,520 vibrations, or sometimes to 4,224; while the highest note of the orchestra is that of the piccolo flute, with 4,752 vibrations per second. The limits of hearing vary in different persons. The squeak of the bat, the sound of the cricket, and even the chirrup of the sparrow, cannot be heard by some persons. The limit of sensibility often varies by as much as two octaves.

Waves of water, as everybody knows, vary greatly in magnitude; the riplets of the pool may be not more than an inch in length, while the sea-waves may measure a hundred feet from crest to crest. Sound-waves also vary greatly in magnitude, though to each rate of vibration there corresponds a definite length of wave. Knowing the rate of vibration per second, and the velocity of sound per second, lengths of waves are easily calculated. Take, for example, a tuning-fork that sounds the lowest note of the common D-flute, and it gives 288 vibrations per second. If, now, it be struck in still air, at the freezing-point, the foremost wave will reach a distance of 1,090 feet, at the end of a second, while the chain of waves which connects it with the vibrating fork will be 288 in number: each wave-link will therefore be about 3 feet 9 inches long. With few vibrations and deep tones, waves are long, while, with rapid vibrations and shrill tones, waves are correspondingly short. Within the limits of hearing, sound-waves vary in length, from 70 feet to a half an inch. "The waves generated by a man's organs of voice in common conversation are from 8 to 12 feet; those of a woman are from 2 to 4 feet in length. Hence, a woman's ordinary pitch, in the lower sounds of conversation, is more than an octave above a man's; in the higher sounds it is two octaves."

But, because the numbers of their oscillations are exactly determined, we must not suppose that the motions are so simple, for, as Prof. Rood remarks, smooth and clean-cut waves but seldom reach the ear. There are compound vibrations which give complexity to wave-figures. The large waves at sea are often covered by smaller waves, so that the water-particles obey double impulses, and swing in double oscillations. It was illustrated, in Fig. 1, that a string may vibrate as a whole, or in various subdivisions. When a string or any other body vibrates as a whole, it produces its lowest note, which is called the fundamental note. But the fundamental note is never perfectly pure. It is not possible to sound the string as a whole, without at the same time causing the vibrations of its parts. But, as these shorter vibrations are quicker, they yield notes of a higher pitch, which mingle with the fundamental note, and alter its quality. These accompanying higher notes may be in harmony with the fundamental note (when they are called *harmonics*), or they may not harmonize with it. The sounds emitted by the *parts* of a vibrating body are called *overtones*, and it is possible for a string to furnish as many as 20 or 30 of these. The mingling of the overtones with the fundamental one determines the *timbre* of sound. It is this which gives their peculiar character to different musical instruments, and enables us to distinguish them. A clarinet and a violin may give the same fundamental note, but their overtones are so different that the instruments are never confounded.

Sound-waves are not only transmitted by the air, but also by liquids and solids. That water will convey musical sounds is shown by the following experiment: Fig. 8 represents a tube a yard long, set upon the wooden tray A B, with a funnel at the top, and filled with water. A tuning-fork is attached to a little wooden foot, set into vibration, and the foot is then dipped into the water without touching the sides of the funnel. The vibrations are transmitted by the liquid to the tray below, which is thrown into tremors, and a swelling musical sound is the result.

Fig. 8.



Vibrations conveyed through Water.

The following beautiful experiment, described by Prof. Tyndall, shows how music may be transmitted by an ordinary wooden rod. In a room two floors beneath his lecture-room, there was a piano upon which an artist was playing, but the audience could not hear it. A rod of deal, with its lower end resting upon the sounding-board of the piano, extended upward through the two floors, its upper end being exposed before the lecture-table. But still no sound was heard. A violin was then placed upon the end of the rod, which was thrown into resonance by the ascending thrills, and instantly the music of the piano was given out in the lecture-room. A guitar and a harp were substituted for the violin, and with the same result. The vibrations of the piano-strings were communicated to the sounding-board, they traversed the long rod, were reproduced by the resonant bodies above, the air was carved into waves, and the whole musical composition was delivered to the listening audience.

The instrument of hearing in man consists of an external orifice about an inch and a half deep in adults, which is closed at the bottom by the circular tympanic membrane. This membrane, though moderately strong, is quite thin, and almost transparent. It is made up of fine fibres, some radiating from the central part to the circumference, and others arranged in concentric rings. It is kept gently on the stretch by two small muscles, one of which draws it tighter, and the other loosens it, by acting upon a chain of small bones. We shall not undertake to describe the curious and complicated anatomy of the inner ear—the drum, containing air, the curious chain-work of minute vibrating bones, the labyrinth filled with water containing little crystalline particles and fine elastic bristles, and where the delicate fibres of the auditory nerve commence. "There is also," says Tyndall, "in the labyrinth a wonderful organ discovered by the Marchese Corti, which is, to all appearance, a musical instrument, with its chords so stretched as to accept vibrations of different periods, and transmit them to the nerve-filaments which traverse the organ. Within the ears of men, and without their knowledge or contrivance, this lute of 3,000 strings (as Kölliker estimates) has existed for ages, accepting the music of the outer world, and rendering it fit for reception by the brain. Each musical tremor which falls upon this organ selects from its tensioned fibres the one appropriate to its own pitch, and throws that fibre into unisonant vibration. And thus, no matter how complicated the motion of the external air may be, those microscopic strings can analyze it, and reveal the constituents of which it is composed." By this wonderful apparatus are all the tremulous movements of the outer world translated to the world within. How the auditory nerve transmits its impressions is not a matter of demonstration, but the probability is great that it transmits them as it receives them as impulses of motion—waves of force that are conveyed to the brain and expended in the production of those physical motions which are the material conditions and accompaniments of consciousness. That the organ of feeling and thought is itself a sphere of vibrations and wave-actions traversing in all directions the millions of microscopic fibres which pervade the encephalon, will be thought absurd by many: but we know that wave-action is a part of the method of Nature; that it produces the most wonderful effects in all the common forms of matter; that the brain is a material instrument in the closest physical relation with the outward order; and that material changes of some kind within it are the concomitants of its exalted functions. That there should be unity in the whole scheme does not appear irrational.

Be this as it may, the marvels of what is known are inexhaustible. Could we see what takes place in a room when a tuning-fork is in vibration, giving out a single note, we should behold all the particles of the air agitated in tremulous sympathy, and filling the space with swiftly-expanding spheres of spectral beauty. Or, were the effect produced by several instruments concurrently played, we should see the forms in countless variety carving the air into ever-changing figures of geometrical harmony, and creating the perfect music of geometrical form. Such a revelation is impossible, from the swiftness of movement, which would foil the eye; but it would be also impossible, because the complications of movement would confuse it. But, where the optical sense fails, the auditory sense succeeds. The membrane of the ear receives the torrent of motion, and transmits it with all its harmonies. In an orchestra, where scores of instruments are playing through the whole compass of the scale, the air is cut into waves by every complexity of vibration—grave tones mingle with shrill, soft with harsh, fundamentals are merged in overtones, and the storm of impulses is shot with the speed of rifle-bullets against the tympanum; and yet there is no confusion. In all their infinite diversity of qualities the waves are legible to the little membrane. It vibrates to the lowest and to the highest, to each and all, and telegraphs the whole performance with incomprehensible exactness to its cerebral destination; and an exquisite work of art is produced in the sphere of pleasurable feeling and critical intelligence.

Our glance at this fascinating subject has been very imperfect, but, if any care to pursue it, we recommend them to the admirable book of Prof. Tyndall, "On Sound," to which we are indebted for the foregoing illustrations, and for many of the facts stated.

INSTINCT IN INSECTS.

By GEORGE POUCHET.

TRANSLATED FROM THE FRENCH, BY A. R. MACDONOUGH, ESQ.

I.

WHAT is instinct? In what does it differ from intelligence? What explanation can be given of it in the present state of the sciences of life? All these are questions to which a positive answer is asked for the first time in our day. Philosophers and moralists do not in our time concern themselves with the relations or the differences between instinct and intelligence; for they have no means of solving problems that particularly concern biology. Without going farther back, we remember Descartes's strange notion of animal machines, adopted by Bossuet, and the whole seventeenth century; but at this time biologists in their turn attack the problem; anatomy and physiology will perhaps give us the solution sought in vain at the hands of philosophic and religious systems since the days of Aristotle and St. Thomas.

George Cuvier was the first to draw a clear distinction between instinct and intelligence, in the second edition of the "Animal Kingdom" (1829), in which he digests the works published during the course of several years, by his brother Frédéric. The latter, placed in control of the menagerie of the museum, believed that it pertained to the duties of his post to make a course of connected studies upon the animals committed to his charge: he thought, as Geoffroy Saint-Hilaire did, that such is the sole purpose of establishments of that kind. "There exists in animals," Cuvier tells us, "a faculty distinct from intelligence, which we term instinct. It makes them do acts which each individual performs without ever having seen them done, and which are repeated, from generation to generation, invariably the same. Without having learned, the animal knows; it knows from its birth, and knows so well, that it never makes a mistake, even in acts of extreme complexity, the secret of which it seems to bring with it into the world. Young ducks hatched under a hen go straight to the nearest piece of water, and boldly plunge and swim, in spite of their foster-mother's cries and distress. The squirrel lays up its winter stock of hazel-nuts and filberts, before it knows what winter is. The shepherd's dog and the pointer know how to do the duties expected of them, through a gift at birth. The bird hatched in a cage and reared a captive, if set free, will build a nest like that its parents built, on the same tree, of the same materials, in the same shape. The spider, more amazing still, weaves without any lessons the geometric net-work of its web; and the untaught bee builds its comb. Man too has his instinct, as animals have. By instinct the new-born child feels for and finds its mother's breast; but instinctive phenomena in man are less easy to determine, and their discovery demands careful research, because intelligence usually veils them. And yet intelligence is not wanting in animals either, only with them instinct has that predominance which intelligence takes in man."

With the exception of a few mistakes in details, Cuvier marked very accurately the line between the instinctive and the intellectual faculties, but he went no further. His character and disposition gave him but little taste for penetrating into problems of that kind. With a lofty disdain to which posterity has done justice, he left to his rival Geoffroy Saint-Hilaire the care of inquiring into the origins of vital manifestations. Cuvier affirmed simply that every species received at its beginning a certain share of intelligence, with a certain provision of instinct, so wisely proportioned as to insure the permanence of that species till the end of time, or at least till the next revolution in our globe. The intelligent race does its part with its faculties as it can; they must suffice for it. The race without intelligence, to make up for its want, brings into the world a supply of instinct which aids it to make its way. This odd theory of compensation, instinct and intellectual faculties respectively complementing each other, misled Cuvier; it agreed with the general scope of his doctrine; but it does not agree with facts. Those among animals that present the most highly-developed instinct are, unquestionably, the insects; the silky tissues of cocoons, the structures wrought by wasps, the beautiful works that are treasured in cabinets, bear witness to astonishing instinctive faculties; every thing seems to be instinct with the insects, and, if Cuvier's idea be adopted, it ought in general to be very poorly endowed as regards intelligence. We shall presently see that the truth is completely the reverse.

Besides, Cuvier had no very accurate knowledge of insects, which in his classification he degraded to a place below molluscs. We cannot address the same reproach to M. Emile Blanchard, who pursues the natural history of articulated animals, at the Jardin des Plantes. We regret keenly that in his late work on the "Transformations, Habits, and Instincts of Insects," he has not thought fit to follow the suggestions of such a title, and to dwell a little on that twofold subject of intelligence and instinct which would gain by being clearly stated. His usual studies and the direction of his labors enable M. Blanchard better than any one else to complete a blank which must be supposed one of choice only, in his work. The learned professor of the museum goes on from Cuvier's starting-point with him, and, with Flourens in his last work ("Comparative Psychology," 1865), M. Blanchard distinguishes instinct from intelligence, but he stops there. He makes no attempt whatever to measure the reciprocal influence of these two kinds of faculties in the very complex acts of insect-life; and, above all, he refrains from the study of their intelligence, full of interest as it is. "Individuals of the same species," he says, "always perform the same works without having learned any thing; instinct alone guides them." Yet, together with this instinct, as M. Blanchard himself admits, there are faculties of intellect, which offer greater difficulties of study by reason of the existence of those instinctive faculties. These very difficulties make the study more worthy of attention. How are the two classes of faculties combined? If that winged mite had nothing but the instincts that urge it, those alone would make it interesting; how is that interest increased, when in that tiny body instinct is paired with reflection that analyzes sensations, and will that determines movements! what a study might we find in these intellectual faculties used by so perfect an instinct! Does it not become indispensable to measure these faculties exactly in the case in which instinct is most developed? Suppose we were to find, contrary to Cuvier's opinion, that instinct, far from being inversely proportioned to the degree of intelligence, is just the reverse, and is greater, according as intelligence is more active.

This really is the truth, and it is important to fix this first point clearly in the study of instinct. Human inferiority in point of instinct is perhaps only apparent, since education hardly allows us to guess what we should be without it. We know from the history of more than one child found wild in the woods, especially from that of the idiot boy so well studied by Itard, what amazing instincts may be displayed by a human creature, even one absolutely without understanding, when abandoned to itself. Among all animals, insects are assuredly those in which instinct is most developed; we except neither birds with their nests, nor beavers with their dams. Among insects, those in which the highest expression of instinct is noted are bees, that build cells like the work of profound geometry; and particularly ants, acting with instincts yet higher, which seem to approach those perhaps smothered by education in man. A Genevese, Peter Huber, made these known to us. His book (1810) crowns a period of remarkable studies upon insects. Before his time, as far back as 1705, a woman, Mlle. Sybille de Merian, crossed the ocean and made a voyage to Surinam, to paint the caterpillars of the tropics; then after her come Réaumur, Da Geer, Bonnet, who watches night and day his flea, the daughter of five virgin generations, and, when it dies, writes to all Europe to disclaim any responsibility for the event. The pursuit grows a passion. Lyonnet passes his life in describing, drawing, and engraving the anatomy of the willow-caterpillar. Enthusiasm works miracles; Francis Huber, the father of the man of ants, although blind, performs the marvel of making wonderful discoveries as to things taking place in the inner darkness of beehives. Peter Huber, the son, is lost and absorbed in those societies of the ants to which he devotes his studies. While all Europe is agitated by coalitions, nothing from without reaches him.

Peter Huber observes and experiments with rare sagacity. No fact escapes him; he may remark upon it or explain it ill, but he notes it most accurately. His observations have not been contradicted; his experiments still remain patterns of care and patience. He peopled with ants, his garden, the terrace of his house, his study, his tables, which were turned into a kind of hives, and, lest this new dwelling might be unsatisfactory to the ants, and in order that they might keep at work in it, he made rain and fair weather for them; his rain-making consisting in rubbing his hand for hours at a time over a wet brush. In brief, he supplied them so richly with tempting dainties and weather-contrivances, that at last they wanted nothing better than their chance home, a bureau-drawer. Did he not even one day cherish the fantastic notion of bringing up the larvæ of his ants by feeding by hand? We cannot resist loving him for his attachment to these little, thinking beings. He meditated long over one decisive experiment—nothing less than the question of setting two colonies of ants at war on the floor of his study. He hesitated and lingered to awake the *casus belli* which should be the signal of slaughter; he devised pretexts to adjourn the dreadful scene. "I thought over this experiment for a long time," he says, "and I constantly postponed it, because I had grown to be very fond of my captives." This recalls one of Réaumur's sayings. He observes with what celerity humble-bees rebuild their nest of moss after it has been opened to examine the inside, an intrusion which these insects allow much more patiently than honey-bees do, and he adds: "If the moss from above is thrown down pretty near to the foot of the nest, as one would naturally do without even thinking that it ought to be done to save the insects some trouble, they very soon busy themselves with putting it back in its place." To save the insects some trouble! What a love for Nature the eighteenth century had, and how differently things are done nowadays! Our entomologists study their ant-hills spade in hand; a stroke of the pick into the mysteries of that underground dwelling costs their feverish passion for inquiry nothing, and yet what a spectacle rewards such barbarity! If the spade uncovers a house of tawny ants (*Formica fusca*), we see under the arched top a labyrinth of low rooms, of galleries and passages, which penetrates the ground and leads to spacious chambers full of nymphæ in their cocoons, or of larvæ almost as motionless. That ant, larger than the others, which is busily coming and going, is a female; for the common ants, the workmen, have no sex; naturalists call them neuters. The female lays eggs, and some workers, surrounding her, take these, one by one, and pile them in little heaps. The worms, when hatched, would perish without the workers, being able only to lift their heads to show their want of food; a worker comes up and lets them take from between its mandibles such nourishing juices as it has brought from its quest in the fields. When the hour comes for carrying all these papooses into the sun, they carry them up and spread them out on the arched top. If the heat is too strong, or if it rains, they bring them back again at once into rooms of suitable temperature. When the time of their transformation comes, the larva has spun itself a cocoon, but is quite unable to get out of it alone. It is the duty of the workers again to extract it; they cut the silk, tear the shell, release the weak, new-grown creature, and then the old empty cocoons are stored away in a remote chamber. Thus are produced males, females, and neuters. The males and females fly off; some females will come back to lay eggs in the ant-hill; the neuters do not leave it. As soon as they have gained a little strength, they set about all those labors that instinct teaches them—the repair and keeping in order of the ant-hill, inside and without, carrying of useful materials, pursuing plant-lice, and gathering stores of all kinds. Assuredly, these instincts alone are very wonderful; but there remains still another to be spoken of, peculiarly conferred on certain species, and which is indisputably the highest of all those we know among animals.

Peter Huber discovered it on the afternoon of the 17th of June, 1804. The date is a memorable one for biology. He was walking in the environs of Geneva, between four and five o'clock in the evening, when he saw a regiment of great red ants crossing the road. They marched in good order, with a front of three or four inches, and in a column eight or ten feet long. Huber followed them, crossed a hedge with them, and found himself in a meadow. The high grass plainly hindered the march of the army, yet it did not disband; it had its object, and reached it. This was the nest of another species of ants, blackish-gray ones, whose hill rose in the grass twenty steps from the hedge. A few blackish-gray ones were scattered about the hill; as soon as these perceived the enemy, they darted upon the strangers, while others hurry into the galleries to give the alarm. The besieged ants come out in a body. The assailants dash upon them, and, after a very short but very spirited struggle, drive the black-gray ones back to the bottom of their holes. One army corps presses after them into the galleries, while other groups labor to make themselves an opening with their teeth into the lateral parts of the hill. They succeed, and the remainder of the troop makes its way into the besieged city by the breach. Peter Huber had seen battles and exterminations of ants before this; he supposed they were slaughtering each other in the depths of the caverns. What was his amazement, after three or four minutes, when he saw the assailants issue hurriedly forth again, each holding between its mandibles a larva or a nympha of the conquered tribe! The aggressors took exactly the same road again by which they had come, passed through the hedge, crossed the road, at the same place, and made their way, still loaded with their prey, toward a field of ripe grain, into which the honest citizen of Geneva, respecting another's property, refrained, with regret, from following them.

This expedition, worthy of the annals of barbarian piracy, inspired Huber with an amazement easy to understand. He examined, and discovered, to his great surprise, that some ant-hills were inhabited in common by two kinds of ants, forming two castes. He designates one of these by the name of "amazon or legionary ants; a name strongly suggesting their martial character," he says. The others he calls, very justly, "auxiliaries." The amazons do not work; their duty is fighting and carrying off the nymphæ and larvæ. They choose the hour toward sunset for their warlike raids against the industrious and peaceable tribes of the neighborhood. Whenever the weather is fine, they sally out thus, and levy their tribute of flesh. The auxiliaries, for their part, are employed in all internal duties, and in keeping up and repairing the dwelling. They alone open and close the entrances to the ant-hill, night and morning; they alone (in the species observed by P. Huber) go after provisions, for they feed the whole establishment, even the legionaries, which are idle except when on their forays; they rear with equal care the larvæ of the legionaries and those that are stolen; they alone, in fine, seem to decide upon the material interests of the community, the requisite enlargements, the need of emigration, and the place suitable for it. Peter Huber made one experiment that shows very plainly the absolute dependence of the amazons upon their associates. These fierce warriors do not understand any household work. Huber put thirty amazons into a glazed drawer, covered with earth on the bottom, with a certain number of larvæ and of nymphæ, both of their own kind and of the auxiliary species. A little honey in a corner was provided for the support of the colony. At first, the amazons seemed to pay some attention to the larvæ, carrying them about here and there, but they soon left them. They did not know how to provide themselves with food. At the end of two days some had already died of hunger close alongside the honey-drops, all were languishing, and they had not even built a chamber. "I was sorry for them," says Huber. He put an auxiliary into the drawer. This solitary one restored order, made a house in the earth, gathered the larvæ into it, released several nymphæ of both kinds that were ready to leave the cocoon, and at last saved the lives of those among the amazons that still had breath.

Peter Huber refrains from any comments in describing all these wonders; he leaves each one, as he says, at liberty to draw any conclusions he pleases. This one conclusion is inevitable: We do, then, find among animals artificial societies, communities of beings strangers in race, yet living together, contributing, toward one common end, their different qualities and their individual efforts. The hive is always one family only. A mixed ant-hill is inhabited by individuals belonging to species at least as different as the horse, the ass, the zebra—so different sometimes that zoologists have classed them in distinct genera (*Polyergus formica*). Like provinces subject to the same form of government, every ant-hill has, nevertheless, its local history, explained by external circumstances, by conditions of neighborhood and boundary. Each one has only the principle of its organization in common with the rest. The same legionaries have sometimes one species of auxiliaries and sometimes another, the black-grey or the mason ant, whichever is within their reach, sometimes both together; or there may be two kinds of legionaries, the "polyergus" and the dark-red, living in the same hill, with one or two species of auxiliaries. Some naturalists, Darwin among others, call these frankly "slave-holders," and the others "slaves." These names are unfair. We must guard against any mistake as to the very peculiar nature of the relations existing between the two castes. Each fills a special part in the community, and neither exercises control or despotism in it. If the association, at the outset, rests on violence and abduction, nothing has ever given rise to a suspicion that there is any thing else in a mixed ant-hill than a collection of individuals kept together by special instincts. These names of "slavery" and "republic," applied to such a form of life, are quite void of meaning. Any allusion to politics, to systems, or doctrines of equality, is wholly out of place here; biology alone has the right of giving a name to a social state which is its peculiar subject of study; this territory belongs to it alone.

We have selected these instances because they furnish the most striking proof both of the perfection that instinct may reach, and of the degree of intelligence of which animals are capable which are placed by their nature at an immeasurable distance from man. Peter

Huber did not clearly draw the distinction, nor could he do so in his time, between that which is instinct and that which is the share of intelligence in those acts which he witnessed. It is clear that these two orders of faculties are constantly combined. It is by reason of their perfection in instinct that intelligence appears so clearly in these little beings. The construction of the ant-hill is an act of instinct; the choice and distribution of its materials partake of intelligence. A thousand traits reveal the thought which perceives, deliberates, wills, executes. We may cite the observed fact of a crowd of ants dragging with great effort a beetle's wing toward their hole. The opening is too small, the wing will not go in. The workers drop it a moment, tear down a piece of the wall, and renew their attempt. Some push it from outside, others drag it from within. Fruitless effort! The superb spoil, which will make an entire ceiling, will not pass yet; they drop it once more; the breach is widened, and the wing at last is swallowed up in the cavern, where perhaps ten partitions must be torn down to carry it to the proper place. The wing once got in, they rebuild the wall, and restore its former dimensions to the entrance. We cannot cite, in the case of monkeys watched in captivity in menageries, a single instance so clearly showing deliberation and common judgment.

The social phenomena presented by the higher animals are unfortunately very little known. We know scarcely any thing of what goes on in a habitation of beavers; we know nothing of the habits of the republican sparrow, which builds a city for its nest; the insect communities are the most perfect ones that have been studied hitherto. So soon as a society exists, there are understanding and concurrence of all at every moment to reach a definite object. No zoologist now doubts that insects of the same species may communicate with each other, under certain circumstances, by a language of which the methods elude us. Blanchard says of the ant: "It has its ideas, and communicates them;" but a singular detail of the history of the sacred scarabee shows this still more clearly. The female, as we know, wraps up her newly-laid egg in a ball of manure, the nourishment for the coming grub. The point now is to transport the ball into a suitable place, where it may be buried. The insect rolls along, with its hind-claws, or, if necessary, hoists with its head, this little world, in which the Egyptians found an emblem for their myths. Sometimes the journey is pretty long; the ball, lifted to the ridge of a mole-hill, rolls down the other side, and so much is gained. But, if a rut or a crevice is encountered, the precious globe drops to the bottom, and would be hopelessly lost if the scarabee had only its own strength to depend on for mounting that steep wall. It struggles in vain, and begins again twenty times over; at last it seems to desert its load, and flies off. Wait and watch; after a little while you will see the insect coming back, but not alone now. It is followed by two, three, four, five companions, which all drop down into the place pointed out, combine their efforts, drag out the ball, and set it on its path again. What did the scarabee say to its comrades? how did it make itself understood? how did it bring them back with it? It is not possible to make any positive answer to these questions; what is beyond dispute is, that there was in this case a concert of intelligences knowing how to understand each other and to come together. Nothing more is needed for the assertion that the insect judges, wills, and perhaps speaks, a language of which we know as yet neither the signs nor the organs.

Cuvier, then, was in error when he announced that instinct in animals is in an inverse ratio to their intelligence. The contrary seems rather to be true, and it is at least probable that in those intelligences of insects which feel, will, understand, deliberate, there are, on a finer scale, differences similar to those we remark in the higher animals. The faculty is common to all, but with shades as marked among the wild beasts of menageries as among our domestic animals. One is cross, and another jealous; this one is good-tempered, that other quarrelsome, faithful to the house, or a vagabond in the streets—all are more or less intelligent. In the lower animals these differences have not been as closely observed; in the first place, they are probably less distinctly marked, and in any case they are much more difficult to observe for reasons of all kinds. The small size of the being, its life wholly alien to our own, the predominance of instinct, are all so many impediments; but, on the other hand, the acts we see them perform under our very eyes, the admitted existence of faculties that may be compared with our own, and those of a relatively high order, allow of very little doubt that not only do insects possess a remarkably-developed intelligence, but that this intelligence presents, in consequence of its very development, individual variations, just as in the higher animals.

This is already a great advance upon Descartes, whose strange theory no one at this day, that we are aware of, undertakes to defend; but this is not all—a new step has been taken in these later times. We are beginning, with our better knowledge, to ask whether those intellectual and instinctive faculties, arranged by Cuvier in two parallel series, may not have some common bond, so that one would flow from the other, and instinct, after all, be definitely a product of intelligence. The question has its importance. Instinct would then no longer be one of those essential properties of living beings which absolutely elude our comprehension, such as thought in the brain, contraction in the muscles, the electricity of the eel, or the gleam of the glow-worm; it would be accessible, like all dependent phenomena, to our processes of experiment and investigation.

Darwin is entitled to the credit of having taken the question into this entirely new region. This bold attempt to found the scientific study of instinct is found rather indefinitely in the "Origin of Species." Darwin does not enter on the problem with deliberate purpose as a physiologist. He continues to be what he is in the whole work, the zoologist, exclusively occupied with his great theory: he foresees and meets objections; he has particularly anticipated those that might be brought against him in the name of instinct; and he gives, in a few pages, a more complete study of instinct than any philosopher had made before him, and the first study ever made by aid of experiment. He ignores instinct as an essential property, and treats it as a function—that is, he explains it. Instinct, as he holds, is nothing but a result from the intellectual faculties, properly so called, modified in a particular way under the twofold power of habit and inherited influence.

Inherited tendency, like intelligence, is one of those properties peculiar to living beings of which we can prove the existence, while its principle completely and absolutely baffles investigation. When we attempt to pierce the mystery by which the plant that springs from the seed, the bird that grows from the yelk, will be more like the plant or the bird it proceeds from than like any other, we confront the impenetrable unknown. Hereditary tendency does not merely carry down from one generation to another all the imaginable modifications of form, size, coloring; it extends to the cerebral faculties, transmitted doubtless by the help of some physical peculiarity of the organ of intelligence. This is what is called the spirit of race, which decides that one people shall be born brave and crafty, like the Greeks of Homer; industrious, like the Chinese; traders, like the Jews; or hunters, like the red-skin. This is, if we choose to term it so, a kind of instinct that education sometimes allows us to control, but never eradicates. As the wolf, fattened in the kennel, ends by going back to his wretched life of the woods, the child of a savage reared in the midst of civilization preserves in his mind, as upon his features, the deep, hereditary stamp of his origin. Habit, almost as much as hereditary tendency, is another mysterious faculty which we recognize without being able to explain it. Some act, most difficult in appearance, which required on the part of our brain a considerable effort of will and all our mental activity, at last surprises us by almost performing itself. We might say that attention and reflection have gone down into our limbs, which perform the most delicate tasks, and protect themselves against attacks from without, while the mind, occupied with something else, is pursuing a different object.—*Revue des Deux Mondes.*

THE DOCTRINE OF NATURAL SELECTION.[1]

By ALFRED R. WALLACE.

NOTWITHSTANDING the objections which are still made to the theory of Natural Selection, on the ground that it is either a pure hypothesis not founded on any demonstrable facts, or a mere truism which can lead to no useful results, we find it year by year sinking deeper into the minds of thinking men, and applied, more and more frequently, to elucidate problems of the highest importance. In the works now before us we have this application made by two eminent writers, one a politician, the other a naturalist, as a means of working out so much of the complex problem of human progress as more especially interests them.

Mr. Bagehot takes for granted that early progress of man which resulted in his separation into strongly-marked races, in his acquisition of language, and of the rudiments of those moral and intellectual faculties which all men possess; and his object is to work out the steps by which he advanced to the condition in which the dawn of history finds him—aggregated into distinct societies known as tribes or nations, subject to various forms of government, influenced by various beliefs and prejudices, and the slave of habits and customs which often seem to us not only absurd and useless, but even positively injurious. Now, every one of these beliefs or customs, or these aggregations of men into groups having some common characteristics, must have been useful at the time they originated; and a great feature of Mr. Bagehot's little book is his showing how even the most unpromising of these, as we now regard them, might have been a positive step in advance when they first appeared. His main idea is, that what was wanted in those early times was some means of combining men in societies, whether by the action of some common belief or common danger, or by the power of some ruler or tyrant. The mere fact of obedience to a ruler was at first much more important than what was done by means of the obedience. So, any superstition or any custom, even if it originated in the grossest delusion, and produced positively bad results, might yet, by forming a bond of union more perfect than any other then existing, give the primitive tribe subject to it such a relative advantage over the disconnected families around them as to lead to their increase and permanent survival in the struggle for ex-

[1] "Physics and Politics; or, Thoughts on the Application of the Principles of 'Natural Selection' and 'Inheritance' to Political Society." By Walter Bagehot. (King & Co., 1872.)

"Histoire des Sciences et des Savants depuis deux Siècles, suivie d'autres Études sur les Sujets Scientifiques, en particulier sur la Sélection dans l'Espèce Humaine." Par Alphonse de Candolle. (Genève: H. Georg, 1873.)

istence. In those early days war was perhaps the most powerful means of forcing men to combined action, and might therefore have been necessary for the ultimate development of civilization. Freedom of opinion was then a positive evil, for it would lead to independent action, the very thing it was most essential to get rid of. In early times isolation was an advantage, in order that these incipient societies might not be broken up by intermixture, and it was only after a large number of such little groups, each with its own idiosyncrasies, habits, and beliefs, had been formed, that it became advantageous for them to meet to intermingle or to struggle together, and the stronger to drive out or exterminate the weaker. Out of the great number of petty tribes thus formed, only a few had the qualities which led to a further advancement. The rest were either exterminated or driven out into remote and inaccessible or inhospitable districts, and some of those are the "savages" which still exist on the earth, serving as a measure of the vast progress of the human race. Yet even these never show us the condition of the primitive man; they are men who advanced up to a certain point and then became stationary:

"Their progress was arrested at various points; but nowhere, not even in the hill-tribes of India, not even in the Andaman Islands, not even in the savages of Terra del Fuego, do we find men who have not got some way. They have made their little progress in a hundred different ways; they have framed with infinite assiduity a hundred curious habits; they have, so to say, *screwed* themselves into the uncomfortable corners of a complex life, which is odd and dreary, but yet is possible. And the corners are never the same in any two parts of the world. Our record begins with a thousand unchanging edifices, but it shows traces of previous building. In historic times there has been but little progress, in prehistoric times there must have been much."

Again our author shows how valuable must have been the institution of caste in a certain stage of progress. It established the division of labor, led to great perfection in many arts, and rendered government easy. Caste nations would at first have a great advantage over non-caste nations, would conquer them, and increase at their expense. But a caste nation at last becomes stationary; for a habit of action and a type of mind which it can with difficulty get rid of are established in each caste. When this is the case, non-caste nations soon catch them up, and rapidly leave them far behind.

This outline will give some idea of the way in which Mr. Bagehot discusses an immense variety of topics connected with the progress of societies and nations, and the development of their distinctive peculiarities. The book is somewhat discursive and sketchy, and it contains many statements and ideas of doubtful accuracy, but it shows an abundance of ingenious and original thought. Many will demur to the view that mere accident and imitation have been the origin of marked national peculiarities; such as those which distinguish the German, Irish, French, English, and Yankees: "The accident of some predominant person possessing certain peculiarities set the fashion, and it has been imitated to this day." And again: "Great models for good or evil sometimes appear among men who follow them either to improvement or degradation." This is said to be one of the chief agents in "nation-making," but a much better one seems to be the affinity of like for like, which brings and keeps together those of like morals, or religion, or social habits; but both are probably far inferior to the long-continued action of external Nature on the organism, not merely as it acts in the country now inhabited by the particular nation, but by its action during remote ages and throughout all the migrations and intermixtures that our ancestors have ever undergone. We also find many broad statements as to the low state of morality and of intellect in all prehistoric men, which facts hardly warrant, but this is too wide a question to be entered upon here. In the concluding chapter, "The Age of Discussion," there are some excellent remarks on the restlessness and desire for immediate action which civilized men inherit from their savage ancestors, and how much it has hindered true progress; and the following passage, with which we will conclude the notice of Mr. Bagehot's book, might do much good if, by means of any skilful surgical operation, it could be firmly fixed in the minds of our legislators and of the public:

"If it had not been for quiet people, who sat still and studied the sections of the cone; if other people had not sat still and worked out the doctrine of chances, the most 'dreamy moonshine,' as the purely practical mind would consider, of all human pursuits; if 'idle star-gazers' had not watched long and carefully the motions of the heavenly bodies—our modern astronomy would have been impossible; and, without astronomy, 'our ships, our colonies, our seamen,' all that makes modern life, could not have existed. Ages of quiet, sedentary, thinking people were required before that noisy existence began, and without those pale, preliminary students it never could have been brought into being. And nine-tenths of modern science is, in this respect, the same; it is the produce of men whom their contemporaries thought dreamers—who were laughed at for caring for what did not concern them—who, as the proverb went, 'walked into a well from looking at the stars'—who were believed to be useless, if any one could be such. And the conclusion is plain that, if there had been more such people; if the world had not laughed at those there were; if, rather, it had encouraged them—there would have been a great accumulation of proved science ages before there was. It was the irritable activity, 'the wish to be doing something,' that prevented it. Most men inherited a nature too eager and too restless to find out things; and, even worse—with their idle clamor they 'disturbed the brooding hen,' they would not let those be quiet who wished to be so, and out of whose calm thought much good might have come forth. If we consider how much good science has done, and how much it is doing for mankind, and, if the over-activity of men is proved to be the cause why science came so late into the world, and is so small and scanty still, that will convince most people that our over-activity is a very great evil."

In the second work, of which we have given the title, the veteran botanist, Alphonse de Candolle, sets forth his ideas on many subjects not immediately connected with the science in which he is so great an authority. The most important, though not the longest, essay in the volume is that on "Selection in the Human Race," in which he arrives at some results which differ considerably from those of previous writers. In a section on "Selection in Human Societies or Nations," we find a somewhat novel generalization as to the progress and decay of nations. Beginning with small, independent states, we see a gradual fusion of these into larger and larger nations, sometimes voluntary, sometimes by conquest, but the fusion always goes on, and tends to become more and more complete, till we have enormous aggregations of people under one government, in which local institutions gradually disappear, and result in an almost complete political and social uniformity. Then commences decay; for the individual is so small a unit, and so powerless to influence the government, that the mass of men resign themselves to passive obedience. There is then no longer any force to resist internal or external enemies, and by means of one or the other the "vast fabric" is dismembered, or falls in ruins. The Roman Empire and the Spanish possessions in America are examples of this process in the past; the Russian Empire and our Indian possessions will inevitably follow the same order of events in a not very distant future.

Although M. de Candolle is a firm believer in Natural Selection, he takes great pains to show how very irregular and uncertain it is in its effects. The constant struggles and wars among savages, for example, might be supposed to lead to so rigid a selection that all would be nearly equally strong and powerful; and the fact that some savages are so weak and incapable as they are shows, he thinks, that the action of natural selection has been checked by various incidental causes. He omits to notice, however, that the struggle between man and the lower animals was at first the severest, and probably had a considerable influence in determining race-characters. It may be something more than accidental coincidence that the most powerful of all savages —the negroes—inhabit a country where dangerous wild beasts most abound; while the weakest of all—the Australians—do not come into contact with a single wild animal of which they need be afraid.

Selection among barbarous nations will often favor cunning, lying, and baseness; vice will gain the advantage, and nothing good will be selected but physical beauty. Civilization is defined by the preponderance of three facts—the restriction of the use of force to legitimate defence and the repression of illegitimate violence, speciality of professions and of functions, and individual liberty of opinion and action under the general restriction of not injuring others. By the application of the above tests we can determine the comparative civilization of nations; but too much civilization is often a great danger, for it inevitably leads to such a softening of manners, such a hatred of bloodshed, cruelty, and injustice, as to expose a nation to conquest by its more warlike and less scrupulous neighbors. Progress in civilization must necessarily be very slow, and to be permanent must pervade all classes and all the surrounding nations; and it is because past civilizations have been too partial that there have been so many relapses into comparative barbarism. All this is carefully worked out, and is well worthy of attention.

In the last section, on the probable future of the human race, we have some remarkable speculations, very different from the somewhat utopian views held by most evolutionists, but founded, nevertheless, on certain very practical considerations. In the next few hundred or a thousand years the chief alterations will be the extinction of all the less dominant races, and the partition of the world among the three great persistent types, the whites, blacks, and Chinese, each of which will have occupied those portions of the globe for which they are best adapted. But, taking a more extended glance into the future of 50,000 or 100,000 years hence, and supposing that no cosmical changes occur to destroy, wholly or partially, the human race, there are certain well-ascertained facts on which to found a notion of what must by that time have occurred. In the first place, all the coal and all the metals available will then have been exhausted, and, even if men succeed in finding other sources of heat, and are able to extract the metals thinly diffused through the soil, yet these products must become far dearer and less available for general use than now. Railroads and steamships, and every thing that depends upon the possession of large quantities of cheap metals, will then be impossible, and sedentary agricultural populations in warm and fertile regions will be the best off. Population will have lingered longest around the greatest masses of coal and iron, but will finally become most densely aggregated within the tropics. But another and more serious change is going on, which will result in the gradual diminution and deterioration of the terrestrial surface. Assuming the undoubted fact that all our existing land is wearing away and being carried into the sea, but, by a strange oversight, leaving out altogether the counteracting internal forces, which for countless ages past seem always to have raised ample tracts above the sea as fast as subaërial denudation has lowered them, it is argued that, even if all the land does not disappear and so man become finally extinct, yet the land will become less varied, and will consist chiefly of a few flat and parched-up plains, and volcanic or coralline islands. Population will by this time necessarily have much diminished, but it is thought that an intelligent and persevering race may even then prosper. "They will enjoy the happiness which results from a peaceable existence, for, without metals or combustibles, it will be difficult to form fleets to rule the seas, or great armies to ravage the land;" and the conclusion is that "such are the probabilities according to the actual course of things." Now, although we cannot admit this to be a probability on the grounds stated by M. de Candolle, it does seem a probability, at some more distant epoch, on other grounds. The great depths of the oceans extend over wide areas, whereas the great heights of the land are only narrow ridges and peaks; hence it has been calculated that the mean height of the land is only 1,000, while the mean depth of the sea is about 15,000 feet. But the sea is $2\frac{1}{2}$ times as extensive as the land, so that the bulk or mass of the land above the sea-level will be only about one thirty-seventh of the mass of the ocean. Now, does not this small proportion of bulk of land to water render it highly probable that the forces of elevation and depression should sometimes cause the total or almost total submersion of the land? Of such an epoch no geological record could be left because there could be no strata formed, except from the *débris* of coral-islands, and such a period of destruction of the greater part of terrestrial life may have repeatedly occurred between the period when the several Primary or Secondary formations were deposited. At all events, with such a proportion of land and sea surface as now exists, with such a small bulk of land above the enormous bulk of water, and with no known cause why the dry land rather than the sea-bottom should be constantly elevated, we must admit it to be almost certain that great fluctuations of the area of the land must occur, and that, while those fluctuations could not very considerably increase the area of the land they might immensely diminish it. There is here, therefore, a cause for the possible depopulation of the earth likely to occur much sooner than any cosmical catastrophe.

The largest and most elaborate essay in the volume is that on the "History of the Sciences and of Scientific Men for the last Two Centuries." In this the author endeavors to arrive at certain conclusions as to the progress of science under different conditions and in different countries, the influence of political institutions and of heredity, and various other phenomena, by a method which is novel and ingenious. He takes account only of the men honored as foreign associates or members by the three great European scientific bodies, the Royal Society of London and the Paris and Berlin Academies. By this means he avoids all personal bias, and secures, on the whole, impartiality. The tables drawn out by this method are examined in every possible way, and the results worked out in the greatest detail. The main conclusion arrived at is the determination of a series of eighteen causes favorable to the progress of science; and it is shown that a large proportion of these are present in a considerable degree in countries where science flourishes, while they are almost wholly absent in barbarous or semi-civilized countries where science does not exist.

Another interesting essay is that on the importance for science of a dominant language, and it contains some very curious facts as to the way in which the English language is spreading on the Continent. M. de Candolle believes that in less than two centuries English will be the dominant language, and will be almost exclusively used in scientific works.

There are also short but very interesting essays on methods of teaching drawing and developing the observing powers of children, on statistics and free-will, and on a few other subjects of less importance, all of which are treated in a thoughtful manner, and illustrate one of the views on which much stress is laid in this work, viz., that the mental faculties which render a man great in any science are not special, but would enable him to attain equal eminence in many other branches of science or in any professional or political career.—*Nature.*

THE BLACK DEATH IN NEW ENGLAND.

By HEZEKIAH BUTTERWORTH, Esq.

THE ancient leprosy, the red plague, and the disease known in Europe as the Black Death, have ceased to afflict mankind. They seem to belong to the evils of the past; their banishment is due to human progress, to a better knowledge of hygiene, and a clearer understanding of the causes that develop infection and produce contagious and epidemic diseases. It is an interesting question to ask, "Will not the small-pox and the cholera, whose effects science has already modified, become extinct diseases?"

The disease known as the black death made its first appearance in Europe at Constantinople in 1347. It was brought there from Asia, probably from the northern coasts of the Black Sea. From Turkey it gradually spread over Europe, almost depopulating whole districts as it travelled north. Florence was terribly smitten. Boccaccio, in the preface to his "Decameron," has left us an account of the sweeping destruction of the Florentines by the scourge, which one who reads can never forget. From Florence it travelled into Spain, swept over France, and crossed the Straits of Dover.

It made its appearance in England late in the summer of 1348. From June to December of that year there was an almost incessant fall of rain. The ground was continually damp, and the streams were polluted by surface drainage. When the sun shone, it was through a misty sky, producing a vapory heat, particularly unhealthy and enervating. In August, a few cases of a disease supposed to be the black death were reported. In September the plague was surely among the people. In November it reached London, and from the capital it rapidly spread into all parts of the kingdom.

The symptoms of this terrible disease, which usually proved fatal, were inflammatory boils and swelling of the glands, similar to those that appear in the worst eruptive fevers, with black patches all over the skin, from which the disease received the name Black Death. The patient was next seized with violent vomitings of blood; he sometimes died at once, and he seldom survived more than two days. It is stated that, toward the end of the pestilence, many lives were saved by puncturing the boils.

It was a fearful time. The population of England and Wales numbered probably between three and four millions, and of these at least one-half, or more than a million persons, perished. Stowe says that the scourge "so wasted and spoyled the people that scarce the tenth person of all sorts was left alive." Another old writer says: "There died an innumerable sort, for no man but God only knew how many." In six months from January 1st there died in the city of Norwich more than 57,000 persons. In the graveyard of Spittle Croft, thirteen acres of land, which was used for the burial of the dead, because the London graveyards were "choke full," there were buried 50,000 persons. Parliament was prorogued in January, on account of the plague having broken out in Westminster, and again in March, on account of the increase of the disease. On the 16th of June, 1350, an important public regulation was made, "because," as the law ran, "a great part of our people is dead of the plague."

Not only the people but the cattle were infected. The disease was highly contagious. Death was in the air. "The pestilential breath of the sick who spat blood," says Hecker, "caused a terrible contagion far and near, for even the vicinity of those who had fallen of the plague was certain death, so that parents abandoned their infected children, and all the ties of kindred were dissolved!"

Half the population, or more than a million souls! What a stretch of the imagination does it require to cover such an appalling calamity! Cities were reduced to towns; towns to hamlets. The work of the husbandman ceased. The dead were unburied, and lay in the fields rotting in the sun. People stayed in their own houses, often half clothed and half famished, waiting for the destroyer to come.

In the year 1664 a similar visitation of the plague came upon London. The disease was perhaps not as swift and violent as had been the black death three hundred years before, but it was of the same general character. It broke out in Drury Lane in December. It had been raging for a considerable period in Holland, and the minds of the English people had been filled with apprehension for months. If Defoe's narrative is true, the people believed that they had supernatural warnings of the impending catastrophe. The symptoms of this disorder were similar to the black death, except that it was usually preceded by dimness of vision, and the discolored patches on the body were livid, instead of black. At the beginning of the following summer the disease fearfully increased. We may get an idea of the scene at the beginning of the calamity, from some little incidents recorded in the journal of Pepys. "June 7th," says this writer, "was the hottest that ever I felt in my life. This day, much against my will, did I see in Drury Lane two or three houses marked with a red cross upon the doors, and 'Lord, have mercy upon us!' writ there—a sad sight to me, being the first of the kind I ever saw." Again, on the 17th of the same month, he says: "It struck me very deep this afternoon, going with a hackney coach down Holborn, from the Lord Treasurer's, I found the coachman to drive *easily and easily*, and the coach stood still. He told me that he was suddenly struck very sick and almost blind. I took another coach, with a sad heart for the poor man, and fearing for myself also, lest he should have been struck with the plague."

As the calamity increased, shops were closed, dwellings were left empty, and the public thoroughfares were deserted. The markets were removed beyond the city-walls, coaches were seldom seen, except when people were fleeing from the city; a solemn stillness prevailed in many districts, and grass grew in the streets. People might be heard crying out of the windows for help, but the cry returned echoless. Some went mad; some rushed into the river, and ended their tortures by suicide. On a single night in the month of September 10,000 people died.

Many incidents of this terrible visitation are preserved, the best known being from the pen of Defoe. Rev. Thomas Vincent describes some touching scenes, of which he himself was a witness. "Among other spectacles," he says, "two, methought, were very affecting; one of a woman coming alone and weeping by the door where I lived, with a little coffin under her arm, carrying it to the new church-yard. I did judge that it was the mother of the child, and that all the family besides were dead."

An old writer thus describes an impressive scene in London during the reign of the plague:

"O unrejoicing Sabbath! not of yore
Did thy sweet evenings die along the Thames
Thus silently. Now, every sail is furled,
The oar hath dropped from out the rower's hand,
And on thou flowest in lifeless majesty,
River of a desert lately filled with joy!
O'er all the mighty wilderness of stone
The air is clear and cloudless, as the sea
Above the gliding ship. All fires are dead,
And not one single wreath of smoke ascends
Above the stillness of the towers and spires.
How idly hangs that arch magnificent
Across the idle river! Not a speck
Is seen to move along it. There it hangs
Still as a rainbow in the pathless sky."

—*John Wilson.*

These are old facts, and are generally well known to the readers of old histories. But it may not be as well known to our readers that the black death, or at least a most malignant form of the true plague, prevailed in North America during the first part of the seventeenth century, sweeping off the Indian tribes on the Atlantic coast, and especially the tribes of New England. In the charter of New England, granted by James I., and bearing date of November 3, 1620, the king states "that he had been given certainly to know, that, within these late years, there hath, by God's visitation, reigned a wonderful plague, etc., to the depopulation of that whole territory, so that there is not left, for many leagues together in a manner, any that do claim or challenge any kind of interest therein."

"These late years" seem to have been 1617, 1618, and 1619. Its ravages from the Narragansett Bay to the Penobscot were of the most fearful character, constantly destroying one-fourth, and, according to some authorities, one-thirtieth of the natives. The old Indians gave a frightful account of it to the Pilgrims, saying that the victims had "died in heaps," and that the disease swept them off so rapidly that "the living were not able to bury the dead."

It is stated that, of the Indians inhabiting Patuxet, Squanto only remained. Norton, in his "New England Canaan" (Amsterdam, 1637), says: "They died in heaps, as they lay in their houses, and the living that were able to shift for themselves would run away and let them dy, and let their carkases ly above the ground without burill. For, in the place where many inhabited, there hath been but one left alive to tell what became of the rest, the living being, it seems, not able to bury the dead. They were left for crowes, kites, and vermine, to pray upon. And the bones and skulls, upon the several places of their habitation, made such a spectacle after my coming into these parts that, as I travelled in that forest near the Massachusetts, it seemed to me a new-found Golgotha." We should add that Mr. Norton came to this country in 1622.

Sir Fernando Gorges, who sent a ship to the East Atlantic coast at this period, tells us that, according to the reports given to him, those of the savages who had escaped the wars had been sore afflicted with the plague: "Notwithstanding, *Vines*" (his navigator), "and the rest with him that lay in the cabins with those people who died, did not so much as feel their heads ache while they stayed there."

It has been stated that the tribe of the Wampanoags was reduced from thirty thousand to a few hundred people, which will account for the small number of braves who appeared with Massasoit during his early visits to Plymouth. The Massachusetts, a tribe about as large as the Wampanoags, according to an early authority, were reduced in like proportion.

Some have supposed that this disease was the yellow fever, because an old Indian had told one of the early historians that the bodies of the deceased turned the color of his blanket, which was yellow. But, in most allusions to it, we find it spoken of as the true plague, or the pestilence in its worst and most destructive form.

The solitude of the forest at this time must have been most solemn and awe-inspiring. Of villages once populous, nothing remained but decaying huts, tenanted by birds and beasts, who had left white and bare the human bones scattered around. The desolations of Athens, of Constantinople, of Florence, and of London, were all unequalled by the spectacle of depopulation that has been presented on our very shores.

The Indian plague becomes an interesting fact of medical science, since it has been supposed that our climate has prophylactic virtues which render the pestilence, that, after an interval of centuries, has again and again ravaged Europe, impossible. We have strong reason to hope that the progress of science has banished this swift minister of death from the civilized races, and that even the modified forms of the disease are gradually yielding and disappearing. Still it is by no means certain that it may not come travelling from the East again, and, if so, we are no more protected by territorial or climatic influences than the inhabitants of the Old World. At least, so we might reasonably infer from this last fearful but interesting chapter of history.

THE NEW PSYCHOLOGY.[1]

By DOUGLAS A. SPAULDING.

TO give readers some idea of the contents of a good book is very often the most useful thing a reviewer can do. Unfortunately, that course is not open to us in the present instance. The subject is too vast. We cannot exhibit the grandeur; we can only in a few general phrases express our admiration of the profound, all-embracing philosophy of which the work before us is an instalment. The doctrine of evolution, when taken up by Mr. Spencer, was little more than a crochet. He has made it the idea of the age. In its presence other systems of philosophy are hushed; they cease their strife, and become its servants, while all the sciences do it homage. The place that the doctrine of evolution has secured in the minds of those who think for the educated public may be indicated by a few names taken just as they occur. Mr. Darwin's works, the novels of George Eliot, Mr. Tylor's "Primitive Culture," Dr. Bastian's "Beginnings of Life," and Mr. Bagehot's "Physics and Politics," have hardly anything in com-

[1] "The Principles of Psychology." In two volumes. By Herbert Spencer. New York: D. Appleton & Co.

mon but the idea of evolution, with which they are all more or less imbued. In a word, we have but one other thinker with whom, in point of influence on the higher thought of this, and probably of several succeeding generations, Mr. Spencer can be classed; it does not need saying that that other is Mr. J. S. Mill.

As we cannot present such an outline of Mr. Spencer's system of psychology as would make it generally intelligible, the purpose of directing attention to the work will perhaps be best served by selecting as the subject of remark one or two points to which the presence of the controversial element may lend a special interest. After pointing out that the cardinal fact brought to light, when nervous action is looked at entirely from the objective point of view, is, that the amount and heterogeneity of motion exhibited by the various living creatures are greater or less in proportion to the development of the nervous system, Mr. Spencer comes to the vexed question of the relation between nervous phenomena and the phenomena of consciousness. This is a subject about which, in its more subtle aspects, there is much uncertainty and some confusion of thought. It may be taken as established, that every mode of consciousness is a concomitant of some nervous change. Given certain physical conditions, accompanied by a special state of consciousness, and there is every reason to believe that physical conditions in every respect identical will always be attended by a similar state of consciousness. This, and not more than this, we think, was intended by Mr. Spencer in his chapter on Æstho-physiology. Nevertheless, several able men have, it would appear, been led to suppose that he countenances a kind of materialism (not using the word to imply any thing objectionable; for why not be materialists, if materialism be truth?), which forms no part of his philosophy. To give precision and emphasis to what we say, we would take the liberty to refer to the position taken up by Dr. Bastian in his remarkably able and important work on the "Beginnings of Life." The expression that definitely raises the issue of which we wish to speak, and which at the same time fixes Dr. Bastian to a view not in harmony with the teaching of Mr. Spencer, is the following: "We have not yet been able to show that there is evolved, during brain action, an amount of heat, or other mode of physical energy, less than there would have been had not the Sensations been felt and the Thoughts thought;" but he believes that this is the case. Our present object is not so much to show that here speculation has got on the wrong track, as that, if we understand Mr. Spencer, it is not his opinion that any thing of this kind takes place; though certainly some ambiguous phrases might be held to convey this meaning. We have mentioned the significant fact that the size of the nervous system holds a pretty constant relation to the amount and heterogeneity of motion generated. The implication is, that none of the motion evolved during nervous action disappears from the object world, passes into consciousness in the same sense that physicists speak of momentum passing into heat; that whether consciousness arise or not, there will be for the molecular motion set up in the nerve-substance exactly the same mechanical equivalents. Whether, for example, those ganglia that in the body of each one of us are employed in carrying on what we call reflex action, are so many distinct seats of consciousness, like so many separate animals, an idea for which much has been said, or whether the nerve-changes that go on in these ganglia have no subjective side; in either case the objective facts will remain the same. If consciousness is evolved, it is not at the expense of a single oscillation of a molecule disappearing from the object-world. No doubt it is hard to conceive consciousness arising in this apparently self-created way; but, if any suppose that by using phrases that would assimilate mind to motion they ease the difficulty, they but delude themselves. It is as easy to think of consciousness arising out of nothing, if they will, as to conceive it as manufactured out of motion; that is to say, the one and the other proposition are alike absolutely unthinkable. On this point Mr. Spencer writes: "Can we think of the subjective and objective activities as the same? Can the oscillations of a molecule be presented in consciousness side by side with a nervous shock, and the two be recognized as one? No effort enables us to assimilate them. That a unit of feeling has nothing in common with a unit of motion, becomes more than ever manifest when we bring the two into juxtaposition." Mr. Spencer's idea is that feeling and nervous action are two faces of the same ontological something—a view that prohibits the notion of the one passing into or being expended in producing the other. The conclusion is, that the transformations of physical energy remain unaffected by the presence or absence of consciousness.

Psychology has as yet been made a serious study by only a few individuals. Accordingly, it is only the more striking and easily grasped peculiarities of Mr. Spencer's system that can be referred to with advantage. Of these, the most imposing, and the one of which the educated public have already a slight second-hand acquaintance, is the doctrine that the brain and nervous system is an organized register of the experiences of past generations, that consequently the intelligence and character of individuals and of races depend much more on this, on the experiences of their ancestors, than on their individual experiences. The flood of light thrown by this conception on so many things previously dark and unfathomable, its power of bringing about harmony where before there was nothing but confusion and unsatisfactory wrangling, ought to have been sufficient to have secured it a universally favorable reception. This, however, has not been the case, and partly, perhaps, because of the very merits that recommend it. It may be that veterans who have won their laurels on, say, the battle-field of innate ideas, love the old controversy, and are not anxious to learn that both sides were right and both wrong. Moreover, it is the misfortune of this important addition to psychology, that it shows that previous workers in this field of inquiry have at times been laboring in the dark to solve problems like in kind with the famous difficulty of accounting for the supposed fact that the weight of a vessel of water is not increased by the addition of a live fish. For instance, should Mr. Spencer be right, the celebrated theory of the Will, elaborated by Prof. Bain, the able representative of the individual-experience psychology, becomes a highly-ingenious account of what does not happen. Thus, the new doctrine can be accepted only at the expense of giving up much of what has hitherto passed for mental science.

The following sentences will serve to indicate Mr. Spencer's position: "The ability to coördinate impressions, and to perform the appropriate actions, always implies the preëxistence of certain nerves arranged in a certain way. What is the meaning of the human brain? It is that the many *established* relations among its parts stand for so many *established* relations among the psychical changes. Each of the constant connections among the fibres of the cerebral masses answers to some constant connection of phenomena in the experiences of the race. . . . Those who contend that knowledge results wholly from the experiences of the individual, ignoring as they do the mental evolution which accompanies the autogenous development of the nervous system, fall into an error as great as if they were to ascribe all bodily growth and structure to exercise, forgetting the innate tendency to assume the adult form. . . . The doctrine that all the desires, all the sentiments, are generated by the experiences of the individual, is so glaringly at variance with facts, that I cannot but wonder how any one should ever have entertained it." The circumstances which account for the existence of the individual-experience psychology, and which enable it still to hold out as a rival of the more advanced form that Mr. Spencer has given to the science, are these: (1) the immaturity of the human infant at birth; (2) the lack of precise knowledge with regard to the mental peculiarities of the lower animals; (3) the still popular notion that the human mind does not resemble the mental constitution of the animals; that it is of a different order. Of course this last is nowadays little more than a popular superstition, nevertheless it can be taken advantage of; and an argument to the effect that the mental operations of the animals are, to all appearance, so very different from the workings of the human mind that they can supply nothing more than a worthless, if not a misleading analogy, has a very specious and scientific look about it in the eyes of those who are not very well acquainted with the subject. Our ignorance of animal psychology may be still more boldly drawn on in defence of the theory under consideration. With a hyper-scientific caution, its advocates refuse to take into account any thing (incompatible with their theory) concerning any one species of animal that has not been proved by a very overwhelmingly large number of very accurate observations. And they find it possible to maintain that it still remains unproved that any species of animal possesses either knowledge or skill not wholly acquired by each individual. A better acquaintance with the mental peculiarities of the animals is certainly a desideratum, and we hope that this rich field of investigation will not long remain uncultivated. In *Macmillan's Magazine* for February there is an account of a series of observations and experiments on young animals by the present writer, which, unless they can be discredited, may reasonably be expected to go far to establish the fact of instinct, the fact of innate knowledge and unacquired skill; in other words, the phenomena on which the experience-psychology, minus the doctrine of inheritance, can throw no light whatever. Now, had not Mr. Darwin banished from every scientific mind the hypothesis of the miraculous creation of each distinct species of animal just as we see it, with all its strange organs, and, to most people, still stranger instincts, the presumption against a system of human psychology that not only can give no account of the most striking phenomena in the mental life of the animals, but which strongly inclines those who hold it to pronounce such phenomena incredible, might not have been so apparent. But, in the present state of our scientific knowledge, such a psychology, professing to be a complete system, is self-condemned. In its fundamental principles the science of mind must be the same for all living creatures. Further, if man be, as is now believed, but the highest, the last, the most complex product of evolution, a system professing to be an analysis and exposition of his mind, yet confessing itself incompetent to deal with the necessarily simpler mental processes of lower creatures, must surely feel itself in an uncomfortably anomalous position.

It is, however, on the first-mentioned circumstance, the immaturity of the infant at birth, that most stress can be laid. The newly-born babe cannot raise its hand to its mouth, and doubtless for a long time after birth it has no consciousness of the axiom, "Things that are equal to the same thing are equal to one another." The helplessness of infancy is pointed to as furnishing ocular demonstration of the doctrine that, whatever may be the case with the animals, all human knowledge, all human ability to perform useful actions, must be wholly the result of associations formed in the life-history of each individual. But it can surely require little argument to show that this is an entirely unwarranted assumption. It might as well be maintained that, because a child is born without teeth and without hair, the subsequent appearance of these must be referred wholly to the operation of external forces. Of the several lines of argument that might here be employed, let us, for the sake of freshness, take the analogy from the lower animals. We are not aware that it can be asserted, as the result of prearranged and careful observations, that any creature at the instant of birth exhibits any of the higher instincts. A number of isolated and more or less accidental observations have been recorded; and apparently on the strength of these Mr. Spencer has made the following unqualified statement. "A chick, immediately it comes out of the egg, not only balances itself and runs about, but picks up fragments of food, thus showing us that it can adjust its muscular movements in a way appropriate for grasping an object in a position that is accurately perceived." The fact is, that, on emerging from the shell, the chick can no more do any thing of all this than can the new-born child run about and gather blackberries. But between the two there is this great difference, that, whereas the chick can pick about perfectly in less than twenty-four hours, the child is not similarly master of its movements in as many months. Our present point is, that it can be shown by experiment that the performances of the chick a day old, which involve the perceptions of distance and direction by the eye and the ear, and of many other qualities of external things, are not in any degree the results of its individual experiences. Let it now be remembered that, in the absence of conclusive evidence to the contrary, it has been considered a safe position to hold that the early knowledge and intelligent action of the chicken "may be, after all, nothing more than very rapid acquisitions, the result of that experimentation, prompted by the inborn or spontaneous activity." May we now, on the other side, similarly presume, until the contrary is shown, that the more tardy progress of the infant is not because its mental constitution has to be built up from the foundation out of the primitive elements of consciousness, which the chicken's has not, but rather because the child comes into the world in a state of greater physical, and therefore mental immaturity? The progress of the infant, however, has been so continually spoken of as if it were a visible process of unaided acquisition, that it may give some surprise when it is asserted from the other side that we have no sufficiently accurate acquaintance with the alleged acquisitions of infancy to justify the doctrine that they are different in kind from the unfolding of the inherited instincts of the chicken. To give definiteness to the attitude taken up, we would say, for example, that the facts concerning the early movements of the two lambs and the calf observed by Prof. Bain, and which, looked at from his point of view, were strong confirmation of the doctrine of individual acquisition, may be just as readily interpreted as the unfolding of inherited powers; which, as far as we know, start into perfect action at the moment of birth, in no single instance. From observations on several newly-dropped calves, the facts corresponding substantially with those recorded by Prof. Bain, the present writer could draw no conclusive evidence in favor of either the one theory or the other. One observation, however, may here be mentioned that seemed rather to favor the doctrine of inheritance. A calf one hour old, which had been staggering about on its legs for ten minutes, stepped out at the open door of the byre. It no sooner found itself in the open air than it began to frisk and dance; it was left entirely to itself, and, when it had been on its legs fifteen minutes, it—apparently in obedience to the feeling of fatigue—deliberately lay down, folding in its limbs after the established manner of its kind. This is all we know about calves; about children we know nothing at all. And it may fairly be asked how, when called in question, the assumption that underlies such statements as the following can be made good. We quote from Prof. Bain's account of the growth of voluntary power. He says: "The infant is unable to masticate; a morsel put into its mouth at first usually tumbles out. But, if there occur spontaneous movements of the tongue, mouth, or jaw, giving birth to a strong relish, these movements are sustained, and begin to be associated with the sensations; so that, after a time, there grows up a firm connection." Bearing in mind that, when born, the child has no occasion for the power of masticating solid food; that the ability to suck, which involves an equally complex series of muscular adjustments, is what it requires, and this it has by instinct; bearing all this in mind, the question is, Why may not the innate ability to masticate be developed by the time it is required quite as spontaneously as the teeth used in the operation? Take a parallel. The feeble nestling when it leaves the shell is blind. One of the several very pronounced and interesting instincts it exhibits at this stage is, that in response to certain sounds it opens its mouth and struggles to hold up its head to be fed. Several weeks later it begins to pick for itself. Now, we put the question, Is this second mode of filling its stomach to be considered a pure acquisition, while its original plan must certainly be regarded as pure instinct? No one, we think, will venture to answer in the affirmative; the more so as this is a case that may any day be put to the test of experiment. Where, then, is the evidence that the analogous progress from drawing milk to masticating solid food is of a different kind?—*Nature.*

OCEAN-CABLES.

By Sir JAMES ANDERSON.

THIS is by no means a new subject for investigation, but in the present day I am certain that it will be instructive to many among the thousands who are now interested in this class of property to have their attention briefly called to all that has been done to make submarine cables a sound property.

Eleven years ago there was a joint committee appointed by the "Lords of the Committee of Privy Council for Trade and Atlantic Telegraphy, to inquire into the construction of submarine cables, together with other evidence." Attention is called in the report to the "remarkable fact that in almost all cases small cables had been found liable to mishaps, while the heavier the cable had been the greater had been its durability." The report is full and complete, and establishes principles which up to the present time have uniformly guaranteed success, while the neglect of them has as uniformly resulted in partial loss or failure.

The loss of cables was found to be attributable to the following causes: First, and the most important of all, from imperfect manufacture, resulting without doubt, prior to this date, from inexperience of the materials for insulating the copper wire, and from ignorance of the fact discovered by Prof. Thomson about 1856, viz., that some kinds of copper wire were no better than iron for the purpose of conductivity, and that it required carefully-selected copper to give the desired standard, which may be represented by a copper wire one tenth of an inch in diameter, being equal to an iron wire one-third of an inch in diameter for electrical purposes. All cables manufactured previous to this date had no advantage from this discovery.

There appear to have been mechanical difficulties in keeping the copper conductor in the centre of the insulating medium, so that the copper was sometimes found to be almost visible under the light film of gutta-percha which covered it. The electric current soon weakened this film, stronger currents were used to overcome the weakness of the signals, and the cable was soon destroyed. Experience about this time had established that a cable from the commencement of its manufacture to the time of its being laid should be tested under water and under pressure, and kept as much as possible under all the conditions in which it was meant to continue.

Attempts to lay cables from sailing-ships towed by steamers was another source of failure. The ships had not enough steerage-way when met with strong head-winds, and too much slack was paid out. It was difficult under such circumstances to steer a straight course, and sailing-ships possessed no power of being readily stopped when a fault or accident occurred.

Many accidents happened from inexperience in the method of paying out cables; at the present day the wonder is, that they should have succeeded so well with the rude methods and inexperience which then existed, and not that there should have been many failures and much recrimination. Reading the history of these first attempts to place a net-work of cables at the bottom of the ocean fifteen and twenty years ago, is a good deal like reading the old stories of the early voyages of discovery. There are difficulties and disasters peculiar to every attempt, and the grand result is that, one way or another, they were overcome, or else they suggested such modifications that their recurrence was avoided, and an accident to a well-manufactured cable no longer constitutes a loss.

The first Atlantic cable failed principally on account of imperfect manufacture, in a great measure arising from undue haste and urgency, but largely owing to insufficient experience. The cable was not tested under water, for fear of rusting the small steel wires of the external covering, and small wires have never since been used; large wires, the larger the better, is now a principle. The copper was not all good. It had often been coiled and uncoiled, and had been exposed to the strong heat of the sun, and to many changes of temperature. Any of these conditions would nowadays be regarded as enough to condemn the most carefully-manufactured cable.

The Red Sea and Indian cables are said to have been imperfectly manufactured and laid too taut, but they were not tested under water from the time of manufacture until they were placed at the bottom of the sea, and this one grand omission, largely due to inexperience, is enough, without the recriminatory points, to condemn to loss and failure any cable whatever.

The cables laid from Cagliari to Malta and Malta to Corfu are said to have failed from imperfect manufacture. One experienced gentleman in his evidence said these cables were "such as nobody should have laid in deep water." It is sufficient at present to know that they have failed from neglect or inexperience, and that they, among other failures, have established the principles which have since insured success.

The want of constant supervision by engineers, exclusively in the interests of the purchasers of the cable, has been a great cause of defective cables. There may often be minute defects in the core itself, or a slightly defective splice which may reduce the electrical condition of a comparatively short length; this may easily be raised above the average standard required by the contract, by the next length being more carefully manufactured. These minute defects must, however, kill the cable in more or less time, and the principle is established that every inch should be tested in course of manufacture, and rejected if there is any irregularity of condition to cause suspicion. There should be constant supervision, and a record of all the tests kept for the purchasers of the cable from the commencement of the contract to its final completion, and continued ever afterward by the purchasers.

The principal sources of injury to cables are—first, moving water, either currents or tides, chafing the cables upon rocks or shingle. Experience has given many costly lessons of the effect of moving water.

Ten years ago it was generally believed that water had very little motion below 50 fathoms, and 100 fathoms was considered a point of great safety. We now know that there are exceptional localities where there is motion in the water at a depth of 500 fathoms. The Falmouth cable was chafed and destroyed at this depth from this cause. The Channel Islands cable was also destroyed from the same cause. The first cable ever manufactured with due regard to the principle of careful supervision, testing under water, and being retained quietly in that condition until it was laid, was the Malta and Alexandria cable, laid in 1861. This cable was submerged in too shallow water, for many miles in less depth than 20 fathoms; the result was the frequent recurrence of fracture from being rolled about by the surf, and yet this cable was only finally abandoned last year; not because it could not be kept in repair, but because it was too expensive to keep in order. These and many other examples have established the principle that no cable should be laid without first obtaining an accurate survey of the approach to the coast and landing-places, with accurate soundings over the intended route, and as much knowledge as possible of the nature of the bottom. Currents and anchorage should be avoided, and, where that is impossible, the heaviest cable that can be laid should be provided. Heavy cables should be laid out to depths of 400 fathoms, where there are tide-ways. Where a current exists, a position should be sought for as far removed from it as possible. A great cause of injury to cables is the corrosion of the external wires, caused by moving water or marine vegetation, etc., and this has established the general practice of covering the external wires with tarred yarn saturated with a mixture of pitch and silica. There is still great room for improvement upon the present method of protecting the external covering of cables, and I commend it to the further careful study of telegraph-engineers as a subject of vital importance.

Another enemy of submarine cables is the *teredo* [1] of all kinds; there is one kind which has proved destructive by boring through the core, but that has only occurred in shallow water; there is another kind which destroys the hemp in a few months, and is then satisfied to fix itself upon the gutta-percha and remain there. Cables have been recovered from depths of 1,200 fathoms with all the hemp eaten away, and the core pitted with these marine animals. The recovery is then only possible by the strength of the external wires.

All the experience we have points to the value of protection, first, of the core, then of the external covering, and, if those responsible for the safety and maintenance of submarine cables could be allowed to dictate the most desirable conditions of safety, they would select, besides the strongest possible cable to be manufactured, and laid with extreme care, a depth of water of about 500 fathoms, and a bottom of sand or mud; but, as this cannot always be secured, nothing should be omitted in the direction of strength and quality.

Lightning is still another source of injury to cables; this is, however, so readily guarded against that we no longer hear of injury from this cause: it is said to have destroyed three cables. Mr. Siemens produced before the committee a piece of the core of the Corfu cable injured by lightning; the land-line had been struck, and, from the absence of any lightning-guards, the cable was damaged. Mr. Preece described the Jersey cable as having been destroyed by lightning. Mr.

[1] *See* article, in this number, on the "Borers of the Sea."

Fleeming Jenkin has seen a fault 18 inches long due to this cause, and it is asserted that the same cause destroyed the Toulon-Algiers cable, which was connected to the land-lines without lightning-guards.

We are every now and then startled by the announcement that light cables are to be preferred to the present iron-clad type, and the object of this investigation has been to discover what data there are to justify any preference to one form of cable over another. I have said already that the committee called attention to the remarkable fact that, in almost all cases, small cables have been found liable to mishaps, while the heavier the cable the greater had been its durability.

Mr. Newall, in his evidence, said that the hemp-covered cable which he attempted to lay in 1859, between Candia and Egypt, had the hemp eaten off by the *teredo* in a very short time, and it was too weak to recover for repairing. The same firm laid an unprotected core from Varna to the Crimea, and it lasted until the winter set in; it is frequently said that it was cut by order of the French commander-in-chief, but there is no proof of this, and I am not disposed to believe it. Mr. Woodehouse, the engineer who laid this core, said in his evidence he "should not advise anybody to lay so light a cable across the Atlantic, because so small a strain would break it. If it is once safe at the bottom, perhaps it may rest." Mr. Newall said he thought it folly to lay any thing excepting unprotected core. Consistently with this conviction, he laid in 1869 several lines of unprotected India-rubber core, connecting the Grecian islands with the main-land; they were protected only near the shore. The sea is quiet and tideless in those parts; no better spot could be wished for the experiment, yet they every one of them gave out within two years.

The Red Sea cable, covered externally with light wires, and unprotected with bituminous compound, was so rusted in a short time that it could not be lifted for repairs.

Notwithstanding Mr. Newall's partiality for light cables, he suggests at the close of his evidence what I assume he would consider the most perfect form of cable. He would cover the copper with India-rubber, protect this core with steel wires vulcanized, the whole then passed through heat; thus insulating all the wires, he would make the cable in one length, and have no joints. Mr. Fleeming Jenkin, in his report to the International Exhibition of 1862, says:

"So long as the iron wires lasted, the cables frequently continued to work in spite of faults, but sooner or later the iron wires of all these light cables rusted away in parts; so soon as this took place they one and all broke up into short sections; this fact has been observed in depths of 100 fathoms;" the reasons were not obvious to Mr. Jenkin, but he says: "Meanwhile the use of large iron wire seems a sure guarantee against this danger, for as yet no cable covered with wire of the large gauges has ever parted in the manner described. The difficulty is, to find a permanent material which shall retain its strength and continue to afford protection after the cable is laid."

Every word of this can be written at the present moment, that is, ten years later, with exactly the same significance. All cables which have been manufactured and laid upon the principles which were established in 1859 are yet in good working order, and every divergence from these principles has been at best but a costly experiment or utter failure. There is no instance yet of a well-manufactured heavy cable breaking or giving out in deep water after it has been carefully laid free from defects; but there may be much due to the external covering keeping it quiet; there has assuredly been a great deal due to the external covering in the successful submerging, and there is no experience whatever to justify the assumption that an unprotected core would last, even if laid.

It has been urged that an iron-covered cable, suspended from one point to another, gradually becomes weaker, that rust and marine growth or deposit accumulate and break the cable with their weight; but I do not know of any instance in support of the assumption, nor is it at all certain that a simple unprotected core would exist for any length of time, or be in any way better adapted for the supposed conditions. Mr. Latimer Clark, in his evidence, says: "You want a certain degree of weight to enable your cable to sink steadily to the bottom, especially when it has to fall into hollows and cavities, and not lie loosely across elevations."

Again, it is urged that experiments with light cables have been tried in factories or sheds, and the result proves that there are many advantages in their favor; but I am of opinion that no experiments which can be made on shore will sufficiently resemble the exigencies which may occur over a period of several days and nights at sea in storms and darkness, and still less will they prove their fitness for the unknown conditions which may exist at great ocean-depths. I desire to write with great respect for the opinions of the talented men who urge the adoption of light cables; it is my special duty to weigh well and without prejudice all they have to advance; but I think a careful investigation into the experience and practice of the last twenty years establishes conclusively that all light cables have been short-lived, and that all heavy cables have continued working, often under most adverse conditions. It is my own opinion, and I am authorized to say that it is also the opinion of my friend Captain Halpin, who has laid all the cables from Suez to Australia, besides the French Atlantic cable (11,000 miles), and has also recovered and repaired cables from a great variety of depths, that a cable should be as heavy as it can be laid with safety, and admit of being recovered in case of accident. Multiply every precaution which shall increase the strength and keep that strength intact as long as possible.

The best form of light cable I have seen is the copper-covered core invented by Mr. Siemens (No. 8). I should have anticipated that, if any light cable could have been successful, this one would have met all the conditions, excepting that of extreme cheapness, but it has not been so uniformly successful as the heavy iron-clad cables. The very light cable invented by Mr. Varley (No. 21) admits of being laid by having the strain taken off the core by the two hempen strands, the core itself being the third strand of the cable. As a light cable, to be manufactured in a great hurry, and laid to meet some emergency, it has a good deal of merit, but for a deep-sea cable I am of opinion that it would be found too incomplete and unfinished, and that difficulties would be experienced in laying which are not at once foreseen, and that there would be no durability even if successfully laid.

Every day of my experience in watching over the permanence of the 10,000 miles of cable under my care, confirms me in the opinion that too great caution and vigilance cannot be exercised in the making and laying a thread which is to be removed from all human vision forever, and designed to earn dividends by continuing a perfect conductor of electricity. Upward of 30,000 miles of cable have been laid since the report of the committee was printed, eleven years ago, and much experience has been gained of the exigencies incidental to submerging, buoying, grappling, and repairing; but no fact has resulted from all that experience which has established that any one precaution recommended in the report has been superfluous, whereas much has occurred, which I will not particularize, proving that any attempt to disregard any single precaution has resulted in great pecuniary loss or utter failure.

We have many reasons to confirm the belief that a submarine cable, manufactured and laid with strict attention to all known principles, may be regarded as a substantial property, likely to last for any length of time; for there is no evidence whatever upon record which shows any decay of the insulating medium or copper conductor of a well-manufactured cable, i. e., there is no decay inherent in the nature of a cable; all deterioration is external; nor is there any experience whatever to establish that this insulated copper wire will enjoy any durability if unprotected with an external covering.

A light cable or unprotected core must therefore be regarded at best as an experiment, with the chances against the successful laying, and still more against its existing as a permanent property.

I have written enough to illustrate that the present submarine cable is not a haphazard idea, but one which has grown out of many failures and thousands of experiments; all the principles of manufacture and laying down have been established by great anxiety and reflection on the part of the able men who gave their energies to this kind of enterprise prior to 1865. We who have come upon the stage since that date have only discovered that we may not neglect one of all the known principles, but elaborate every one of them, and even then the duty of laying and maintaining this class of property has enough of risks and anxieties to make one heartily dislike any experiment which can only be advocated for the sake of cheapness in the first cost. I believe this economy would be at the expense of security, and that the cable of the future will be even heavier, more perfect, and more costly, than the cable of the present day.—*Abstract of Address before the Statistical Society.*

THE STUDY OF SOCIOLOGY.

By HERBERT SPENCER.

X.—*The Class-Bias.*

MANY years ago, a solicitor, sitting by me at dinner, complained bitterly of the injury which the then lately-established County Courts were doing his profession. He enlarged on the topic in a way implying that he expected me to agree with him in therefore condemning them. So incapable was he of going beyond the professional point of view, that what he regarded as a grievance he thought I also ought to regard as a grievance: oblivious of the fact that the more economical administration of justice, of which his lamentation gave me proof, was to me, not being a lawyer, matter for rejoicing.

The bias thus exemplified is a bias by which nearly all have their opinions warped. Naval officers disclose the unhesitating belief that we are in imminent danger because the cry for more fighting-ships and more sailors has not been met to their satisfaction. The debates on the purchase-system proved how strong was the conviction of military men that our national safety depended on the maintenance of an army-organization like that in which they were brought up, and had attained their respective ranks. Clerical opposition to the repeal of the Corn-laws showed how completely that view which Christian ministers might have been expected to take, was shut out by a view more congruous with their interests and alliances. In all classes and subclasses it is the same. Hear the murmurs uttered when, because of the Queen's absence, there is less expenditure in entertainments and the so-called gayeties of the season, and you perceive that London traders think the nation suffers if the consumption of superfluities is checked. Study the pending controversy about coöperative stores *versus* retail shops, and you find the shopkeeping mind possessed by the idea that society commits a wrong if it deserts shops and goes to stores—is quite unconscious that the present distributing system rightly exists only as a means of economically and conveniently supplying consumers, and must yield to another system if that should prove more economical and convenient. Similarly with the other trading bodies, general and special—similarly with the merchants who opposed the repeal of the Navigation Laws; similarly with the Coventry weavers, who like free-trade in all things save ribbons.

The class-bias, like the bias of patriotism, is a reflex egoism; and, like it, has its uses and abuses. As the strong feelings enlisted on behalf of one's nation cause that enthusiastic coöperation by which its integrity is maintained in presence of other nations, severally tending to spread and subjugate their neighbors; so the *esprit de corps*, more or less manifest in each specialized part of the body politic, prompts measures to preserve the integrity of that part in opposition to other parts, all more or less antagonistic. The egoism of individuals becomes an egoism of the class they form; and, besides the separate efforts, generates a joint effort to get an undue share of the aggregate proceeds of social activity. The aggressive tendency of each class, so produced, has to be balanced by like aggressive tendencies of other classes. The class-feelings do, in short, develop one another; and the respective organizations in which they embody themselves develop one another. Large classes of the community, marked off by rank, and sub-classes marked off by special occupations, everywhere form their defensive combinations, and set up organs advocating their interests; and the reason assigned is in all cases the same—the need for self-defence.

Along with the good which a society derives from this self-asserting and self-preserving action, by which each division and subdivision keeps itself strong enough for its functions, there goes, among other evils, this which we are considering—the aptness to contemplate all social actions in their bearings on class-interests, and the resulting inability to estimate rightly their effects on the society as a whole. The habit of thought produced perverts not merely the judgments on questions which directly touch class-welfare, but it perverts the judgments on multitudinous questions which touch class-welfare very indirectly, if at all. It fosters an adapted theory of social relations of every kind, with sentiments to fit the theory; and a characteristic stamp is given to the beliefs on public matters in general. Take an instance:

Whatever its technical ownership may be, Hyde Park is open for the public benefit: no title to special benefit is producible by those who ride and drive. It happens, however, that those who ride and drive make large use of it daily; and extensive tracts of it have been laid out for their convenience: the tracts for equestrians having been from time to time increased. Of people without carriages and horses, a few, mostly of the kind who lead easy lives, use Hyde Park frequently as a promenade. Meanwhile, by the great mass of Londoners, too busy to go so far, it is scarcely ever visited: their share of the general benefit is scarcely appreciable. And now what do the few who have a constant and almost exclusive use of it think about the occasional use of it by the many? They are angry when, at long intervals, even a small portion of it, quite distant from their haunts, is occupied for a few hours in ways disagreeable to them—nay, even when such temporary occupation is on a day during which Rotten

Row is nearly vacant, and the drives not one-third filled. In this, any one unconcerned may see the influence of the class-bias. But he will have an inadequate conception of its distorting power unless he turns to some letters from members of the ruling class published in the *Times* in November last, when the question of the Park Rules was being agitated. One writer, signing himself "A Liberal M. P.," expressing his disgust at certain addresses he heard, proposed, if others would join him, to give the offensive speakers punishment by force of fists; and then, on a subsequent day, another legislator, similarly moved, writes:

"If 'M. P.' is in earnest in his desire to get some honest men together to take the law into their own hands, I can promise him a pretty good backing from those who are not afraid to take all the consequences.

"I am, sir, your obedient servant, AN EX-M. P."

And thus we find class-feeling extinguishing rational political thinking so completely that, wonderful to relate, two law-makers propose to support the law by breaking the law!

In larger ways we have of late seen the class-bias doing the same thing—causing contempt for those principles of constitutional government slowly and laboriously established, and prompting a return to barbaric forms of government. Read the debate respecting the payment of Governor Eyre's expenses, and study the division-lists, and you see that acts which, according to the Lord Chief-Justice, "have brought reproach not only on those who were parties to them, but on the very name of England," can, nevertheless, find numerous defenders among men whose class-positions, military, naval, official, etc., make them love power and detest resistance. Nay, more, by raising an Eyre-Testimonial Fund, and in other ways, there was shown a deliberate approval of acts which needlessly suspended orderly government and substituted unrestrained despotism. There was shown a deliberate ignoring of the essential question raised, which was—whether an executive head might, at will, set aside all those forms of administration by which men's lives and liberties are guarded against tyranny.

More recently, this same class-bias has been shown by the protest made when Mr. Cowan was dismissed for executing the Kooka rioters who had surrendered. The Indian Government, having inquired into the particulars, found that this killing of many men, without form of law and contrary to orders, could not be defended on the plea of pressing danger; and, finding this, it ceased to employ the officer who had committed so astounding a deed, and removed to another province the superior officer who had approved of the deed. Not excessive punishment, one would say. Some might contend that extreme mildness was shown in thus inflicting no greater evil than is inflicted on a laborer when he does not execute his work properly. But now mark what is thought by one who gives utterance to the bias of the governing classes, intensified by life in India. In a letter published in the *Times* of May 15, 1872, the late Sir Donald McLeod writes concerning this dismissal and removal:

"All the information that reaches me tends to prove that a severe blow has been given to all chance of vigorous or independent action in future, when emergencies may arise. The whole service appears to have been astonished and appalled by the mode in which the officers have been dealt with."

That we may see clearly what amazing perversions of sentiment and idea are caused by contemplating actions from class points of view, let us turn from this feeling of sympathy with Mr. Cowan to the feeling of detestation shown by members of the same class in England toward a man who kills a fox that destroys his poultry. Here is a paragraph from a recent paper:

"Five poisoned foxes have been found in the neighborhood of Penzance, and there is consequently great indignation among the western sportsmen. A reward of £20 has been offered for information that shall lead to the conviction of the poisoner."

So that wholesale homicide, condemned alike by religion, by equity, by law, is approved, and the mildest punishment of it blamed; while vulpicide, committed in defence of property, and condemned neither by religion, nor by equity, nor by any law save that of sportsmen, excites an anger that cries aloud for positive penalties!

I need not further illustrate the more special distortions of sociological belief which result from the class-bias. They may be detected in the conversations over every table, and in the articles appearing in every party-journal or professional publication. The effects here most worthy of our attention are the general effects—the effects produced on the minds of the upper and lower classes. Let us observe how greatly the sentiments and ideas generated by their respective social positions pervert the conceptions of employers and employed. We will deal with the employed first.

As before shown, mere associations of ideas, especially when joined with emotions, affect our beliefs, not simply without reason, but in spite of reason, causing us, for instance, to think there is something intrinsically repugnant in a place where many painful experiences have been received, and something intrinsically charming in a scene connected with many past delights. The liability to such perversions of judgment is greatest where *persons* are the objects with which pleasures and pains are habitually associated. One who has often been, even unintentionally, a cause of gratification, is favorably judged; and an unfavorable judgment is apt to be formed of one who, even involuntarily, has often inflicted sufferings. Hence, where there are social antagonisms, arises the universal tendency to blame the *individuals*, and to hold them responsible for the *system*.

It is thus with the conceptions the working-classes frame of those by whom they are immediately employed, and of those who fill the higher social positions. Feeling keenly what they have to bear, and tracing sundry real grievances to men who buy their labor, and men who are most influential in making the laws, artisans and rustics conclude that, considered individually and in combination, those above them are personally bad—selfish, or tyrannical, in special degrees. It never occurs to them that the evils they complain of result from the average human nature of our age. And yet, were it not for the class-bias, they would see, in their dealings with one another, plenty of proofs that the injustices they suffer are certainly not greater, and possibly less, than they would be were the higher social functions discharged by individuals taken from among themselves. The simple fact, notorious enough, that working-men, who save money and become masters, are not more considerate than usual toward those they employ, but often the contrary, might alone convince them of this. On all sides there is ample evidence having kindred meaning. Let them inquire about the life in every kitchen where there are several servants, and they will find quarrels about supremacy, tyrannies over juniors who are made to do more than their proper work, throwings of blame from one to another, and the many forms of misconduct caused by want of right feeling; and very often the evils growing up in one of these small groups are greater than the evils pervading society at large. The doings in workshops, too, illustrate in various ways the ill-treatment of artisans by one another. Hiding the tools and spoiling the work of those who do not conform to their unreasonable customs, prove how little individual freedom is respected among them. And still more conspicuously is this proved by the internal governments of their trade-combinations. Not to dwell on the occasional killing of men among them, who assert their rights to sell their labor as they please, or on the frequent acts of violence and intimidation committed by those on strike against those who undertake the work they have refused, it suffices to cite the despotism exercised by trades-union officers. The daily acts of these make it manifest that the ruling organizations formed by working-men inflict on them grievances as great as, if not greater than, those which the organization of society at large inflicts. When the heads of a combination he has joined forbid a collier to work more than three days in a week—when he is limited to a certain "get" in that space of time—when he dares not accept from his employer an increasing bonus for every extra day he works—when, as a reason for declining, he says that he should be made miserable by his comrades, and that even his wife would not be spoken to; it becomes clear that he and the rest have made for themselves a tyranny worse than the tyrannies complained of. Did he look at the facts, apart from class-bias, the skilful artisan, who in a given time can do more than his fellows, but who dares not do it because he would be "sent to Coventry" by them, and who consequently cannot reap the benefit of his superior powers, would see that he is thus aggressed upon by his fellows more seriously than by acts of Parliament or combinations of capitalists. And he would further see that the sentiment of justice in his own class is certainly not greater than in the classes he thinks so unjust.

The feeling which thus warps working-men's conceptions, at the same time prevents them from seeing that each of their unions is selfishly aiming to benefit at the expense of the industrial population at large. When a combination of carpenters or of engineers makes rules limiting the number of apprentices admitted, with the view of maintaining the rate of wages paid to its members—when it thus tacitly says to every applicant beyond the number allowed, "Go and apprentice yourself elsewhere;" it is indirectly saying to all other bodies of artisans, "You may have your wages lowered by increasing your numbers, but we will not." And when the other bodies of artisans severally do the like, the general result is that the incorporated workers, of all orders, say to the surplus sons of workers who want to find occupations, "We will none of us let our masters employ you." Thus each trade, in its eagerness for self-protection, is regardless of other trades, and sacrifices numbers among the rising generation of the artisan class. Nor is it thus only that the interest of each class of artisans is pursued to the detriment of the artisan-class in general. I do not refer to the way in which, when bricklayers strike, they throw out of employment the laborers who attend them, or to the way in which the colliers now on strike have forced idleness on the iron-workers; but I refer to the way in which the course taken by any one set of operatives, to get higher wages, is taken regardless of the fact that an eventual rise in the price of the commodity produced is a disadvantage to all other operatives. The class-bias, fostering the belief that the question in each case is entirely one between employer and employed, between capital and labor, shuts out the truth that the interests of all consumers are involved, and that the immense majority of consumers belong to the working-classes themselves. If the consumers are named, such of them only are remembered as belong to the wealthier classes, who, it is thought, can well afford to pay higher prices. Listen to a passage from Mr. George Potter's paper, read at the late Leeds Congress:

> "The consumer, in fact, in so high a civilization, so arrogant a luxuriousness, and so impatient an expectancy as characterize him in our land and age, is ever ready to take the alarm and to pour out the phials of his wrath upon those whom he merely suspects of taking a course which may keep a feather out of his bed, a spice out of his dish, or a coal out of his fire; and, unfortunately for the chances of fairness, the weight of his anger seldom falls upon the capitalists, but is most certain to come crushing down upon the lowly laborer, who has dared to stand upon his own right and independence."

From which it might be supposed that all skilled and unskilled artisans and farm-laborers, with their wives and children, live upon air—need no food, no clothing, no furniture, no houses, and are therefore unaffected by enhanced prices of commodities. However fully prepared for the distorting effects of class-bias, one would hardly have expected effects so great. One would have thought it manifest, even to an extreme partisan of trades-unions, that a strike which makes coal as dear again, affects, in a relatively small degree, the thousands of rich consumers above described, and is very keenly felt by the millions of poor consumers to whom, in winter, the outlay for coal is a serious item of expenditure. One would have thought that a truth, so obvious in this case, would be recognized throughout—the truth that, with nearly all products of industry, the evil caused by a rise of price falls more heavily on the vast numbers who work for wages than on the small numbers who have moderate incomes or large incomes.

Were not their judgments warped by the class-bias, working-men might be more pervious to the truth that better forms of industrial organization would grow up and extinguish this which they regard as oppressive, were such better forms practicable. And they might see that the impracticability of better forms results from the imperfections of existing human nature, moral and intellectual. If the workers in any business could so combine and govern themselves that the share of profit coming to them as workers was greater than now, while the interest on the capital employed was less than now; and if they could at the same time sell the articles produced at lower rates than like articles produced in businesses managed as at present, then, manifestly, businesses managed as at present would go to the wall. That they do not go to the wall—that such better industrial organizations do not replace them, implies that the natures of working-men themselves are not good enough; or, at least, that there are not many of them good enough. Happily, to some extent, organizations of a superior type are becoming possible: here and there they have achieved encouraging successes. But, speaking generally, the masses are neither sufficiently provident, nor sufficiently conscientious, nor sufficiently intelligent. Consider the evidence.

That they are not provident enough they show both by wasting their higher wages when they get them, and by neglecting such opportunities as occur of entering into modified forms of coöperative industry. When the Gloucester Wagon Company was formed, it was decided to reserve a thousand of its shares, of ten pounds each, for the workmen employed; and to suit them it was arranged that the calls of a pound each should be at intervals of three months. As many of the men earned £2 10*s*. per week, in a locality where living is not costly, it was considered that the taking up of shares in this manner would be quite practicable. All the circumstances were at the outset such as to promise that prosperity which the company has achieved.

The chairman is no less remarkable for his skill in the conduct of large undertakings than for that sympathy with the working-classes which led him to adopt this course. The manager had been himself a working-man; and so fully possessed the confidence of working-men that many migrated with him from the Midland counties when the company was formed. Further, the manager entered heartily into the plan—telling me himself that he had rejoiced over the founding of a concern in which those employed would have an interest. His hopes, however, and those of the chairman, were disappointed. After the lapse of a year, not one of the thousand shares was taken up; and they were then distributed among the proprietors. Doubtless, there have been in other cases more encouraging results. But this case is one added to others which show that the proportion of working-men adequately provident is not great enough to permit an extensive growth of better industrial organizations.

Again, the success of industrial organizations, higher in type, requires in the members a nicer sense of justice than is at present general. Closer coöperation implies greater mutual trust; and greater mutual trust is not possible without more respect for one another's claims. When we find that in sick-clubs it is not uncommon for members to continue receiving aid when they are able to work, so that spies have to be set to check them; while, on the other hand, those who administer the funds often cause insolvency by embezzling them; we cannot avoid the inference that want of conscientiousness must very generally prevent the effective union of workers under no regulation but their own. When, among skilled laborers, we find a certain rate per hour demanded, because less "did not suffice for their natural wants," though the unskilled laborers working under them were receiving little more than half the rate per hour, and were kept out of the skilled class by stringent rules, we do not discover a moral sense so much above that shown by employers as to promise success for industrial combinations superior to our present ones. While workmen think themselves justified in combining to sell their labor only on certain terms, but think masters not justified in combining to buy only on certain terms, they show a conception of equity not high enough to make practicable a form of coöperation requiring that each shall recognize the claims of others as fully as his own. One pervading misconception of justice betrayed by them would alone suffice to cause failure—the misconception, namely, that justice requires an equal sharing of benefits among producers, instead of requiring, as it does, equal freedom to make the best of their faculties. The general policy of trades-unionism, tending everywhere to restrain the superior from profiting by his superiority lest the inferior should be disadvantaged, is a policy which, acted out in any industrial combinations, must make them incapable of competing with combinations based on the principle that benefit gained shall be proportioned to faculty put forth.

Thus, as acting on the employed in general, the class-bias obscures the truth, otherwise not easy to see, that the existing type of industrial organization, like the existing type of political organization, is about as good as existing human nature allows. The evils there are in it are nothing but the evils brought round on men by their own imperfections. The relation of master and workman has to be tolerated, because, for the time being, no other will answer as well. Looked at apart from special interests, this organization of industry we now see around us must be considered as one in which the cost of regulation, though not so great as it once was, is still excessive. In any industrial combination there must be a regulating agency. That regulating agency, whatever its nature, must be paid for—must involve a deduction from the total proceeds of the labor regulated. The present system is one under which the share of the total proceeds that goes to pay for regulation is considerable; and, under better systems to be expected hereafter, there will doubtless be a decrease in the cost of regulation. But, for the present, our comparatively-costly system has the justification that it alone succeeds. Regulation is costly because the men to be regulated are defective. With decrease of their defects will come economy of regulation, and consequently greater shares of profit to themselves.

Let me not be misunderstood. The foregoing criticism does not imply that operatives have no grievances to complain of; nor does it imply that trade-combinations and strikes are without adequate justifications. It is quite possible to hold that when, instead of devouring their captured enemies, men made slaves of them, the change was a step in advance; and to hold that this slavery, though absolutely bad, was relatively good—was the best thing practicable for the time being. It is quite possible also to hold that when slavery gave place to a serfdom under which certain personal rights were recognized, the new arrangement, though in the abstract an inequitable one, was more equitable than the old, and constituted as great an amelioration as men's natures then permitted. It is quite possible to hold that when, instead of serfs, there came freemen working for wages, but held as a class in extreme subordination, this modified relation of employers and employed, though bad, was as good a one as was then practicable. And so it may be held that at the present time, though the form of industrial government entails serious evils, those evils, much less than the evils of past times, are as small as the average human nature allows—are not due to any special injustice of the employing class, and can be remedied only as fast as men in general advance. On the other hand, while contending that the policy of trades-unions, and the actions of men on strike, manifest an injustice as great as that shown by the employing classes, it is quite consistent to admit, and even to assert, that the evil acts of trade-combinations are the unavoidable accompaniments of a needful self-defence. Selfishness on the one side, resisting selfishness on the other, inevitably commits sins akin to those it complains of—cannot effectually check harsh dealings without itself using harsh measures. Further, it may be fully admitted that the evils of working-class combinations, great as they are, are accompanied by certain benefits, and will perhaps hereafter be followed by greater benefits—are evils accompanying the transition to better arrangements.

Here my purpose is neither to condemn nor to applaud the ideas and actions of the employed in their dealings with employers; but simply to point out how the class-bias warps working-men's judgments of social relations—makes it difficult for working-men to see that our existing industrial system is a product of existing human nature, and can be improved only as fast as human nature improves.

The ruling and employing classes display an equally-strong bias of the opposite kind. From their point of view, the behavior of their poorer fellow-citizens throughout these struggles appears uniformly blamable. That they experience from a strike inconvenience, more or less considerable, sufficiently proves to them that the strike must be wrong. They think there is something intolerable in this independence which leads to refusals to work except at higher wages or for shorter times. That the many should be so reckless of the welfare of the few, seems to the few a grievance not to be endured. Though Mr. George Potter, as shown above, wrongly speaks of the consumer as though he were always rich, instead of being, in nine cases out of ten, poor; yet he rightly describes the rich consumer as indignant when operatives dare to take a course which threatens to raise the prices of necessaries and make luxuries more costly. This feeling, often betrayed in private, exhibited itself in public on the occasion of the late strike among the gas-stokers; when there were uttered proposals that acts entailing so much inconvenience should be put down with a strong hand. And the same spirit was shown in that straining of the law which brought on the men the punishment for conspiracy, instead of the punishment for breach of contract; which was well deserved, and would have been quite sufficient.

This mental attitude of the employing classes is daily shown by the criticisms passed on servants. Read "The Greatest Plague in Life," or listen to the complaints of every housewife, and you see that the minds of masters and mistresses are so much occupied with their own interests as to leave little room for the interests of the men and maids in their service. The very title, "The Greatest Plague in Life," implies that the only life worthy of notice is the life to which servants minister; and there is an entire unconsciousness that a book with the same title, written by a servant about masters and mistresses, might be filled with equally-severe criticisms and grievances far more serious. The increasing independence of servants is enlarged upon as a change greatly to be lamented. There is no recognition of the fact that this increasing independence implies an increasing prosperity of the classes from which servants come; and that this amelioration in the condition of the many is a good far greater than the evil entailed on the few. It is not perceived that if servants, being in great demand and easily able to get places, will no longer submit to restrictions, say about dress, like those of past times, the change is part of the progress toward a social state which, if apparently not so convenient for the small regulating classes, implies an elevation of the large regulated classes.

The feeling shown by the rich, in their thoughts about and dealings with the poor, is, in truth, but a mitigated form of the feeling which owners of serfs and owners of slaves displayed. In early times bondsmen were treated as though they existed simply for the benefit of their owners; and down to the present time the belief pervading the select ranks (not indeed expressed, but clearly enough implied) is, that the convenience of the select is the first consideration, and the welfare of the masses a secondary consideration. Just as an Old-English thane would have been astonished if told that the only justification for his existence as an owner of thralls was, that the lives of his thralls were on the whole better preserved and more comfortable than they would be did he not own them; so, now, it will astonish the dominant classes to assert that their only legitimate *raison d'être* is, that by their instrumentality as regulators the lives of the people are, on the average, made more satisfactory than they would otherwise be. And yet, looked at apart from class-bias, this is surely an undeniable truth. Ethically considered, there has never been any warrant for the subjection of the many to the few, except that it has furthered the welfare of the many; and, at the present time, furtherance of the welfare of the many is the only warrant for that degree of class-subordination which continues. The existing conception must be, in the end, entirely changed. Just as the old theory of political government has been so transformed that the ruling agent, instead of being owner of the nation, has come to be regarded as servant of the nation; so the old theory of industrial and social government has to undergo a transformation which will make the regulating classes feel, while duly pursuing their own interests, that their interests are secondary to the interests of the masses whose labors they direct.

While the bias of rulers and masters makes it difficult for them to conceive this, it also makes it difficult for them to conceive that a decline of class-power and a decrease of class-distinctions may be accompanied by improvement not only in the lives of the regulated classes, but in the lives of the regulating classes. The sentiments and ideas proper to the existing social organization prevent the rich from seeing that worry and weariness and disappointment result to them indirectly from this social system, apparently so conducive to their welfare. Yet, would they contemplate the past, they might find strong reasons for suspecting as much. The baron of feudal days never imagined the possibility of social arrangements that would serve him far better than the arrangements he so strenuously upheld; nor did he see in the arrangements he upheld the causes of his many sufferings and discomforts. Had he been told that a noble might be much happier without a moated castle, having its keep and secret passages and dungeons for prisoners—that he might be more secure without drawbridge and portcullis, men-at-arms and sentinels—that he might be in less danger having no vassals or hired mercenaries—that he might be wealthier without possessing a single serf; he would have thought the statements absurd even to the extent of insanity. It would have been useless to argue that the *régime* seeming so advantageous to him entailed hardships of so many kinds—perpetual feuds with his neighbors, open attacks, surprises, betrayals, revenges by equals, treacheries by inferiors; the continual carrying of arms and wearing of armor; the perpetual quarrellings of servants and disputes among vassals; the coarse and unvaried food supplied by an unprosperous agriculture; a domestic discomfort such as no modern servant would tolerate; resulting in a wear and tear that brought life to a comparatively early close, if it was not violently cut short in battle or by murder. Yet what the class-bias of that time made it impossible for him to see, has become to his modern representative conspicuous enough. The peer of our day knows that he is better off without defensive appliances, and retainers, and serfs, than his predecessor was with them. His country-house is more secure than was an embattled tower; he is safer among his unarmed domestics than a feudal lord was when surrounded by armed guards; he is in less danger going about weaponless than was the mail-clad knight with lance and sword. Though he has no vassals to fight at his command, there is no suzerain who can call on him to sacrifice his life in a quarrel not his own; though he can compel no one to labor, the labors of freemen make him immensely more wealthy than was the ancient holder of bondsmen; and along with the loss of direct control over workers there has grown up an industrial system which supplies him with multitudinous conveniences and luxuries undreamt of by him who had workers at unchecked command.

May we not, then, suspect that, just as the dominant classes of ancient days were prevented by the feelings and ideas appropriate to the then-existing social state from seeing how much evil is brought on them, and how much better for them might be a social state in which their power was much less; so the dominant classes of the present day are disabled from seeing how the existing forms of class-subordination redound to their own injury, and how much happier may be their future representatives having social positions less prominent? Occasionally recognizing, though they do, certain indirect evils attending their supremacy, they do not see that by accumulation these indirect evils constitute a penalty which supremacy brings on them. Though they repeat the trite reflection that riches fail to purchase content, they do not draw the inference that there must be something wrong in a system which thus deludes them. You hear it from time to time admitted that great wealth is a heavy burden: the life of a rich peer being described as made like the life of an attorney by the extent of his affairs. You observe, among those whose large means and various estates enable them to multiply their appliances to gratification, that every new appliance becomes an additional something to be looked after, and adds to the possibilities of vexation. Further, if you put together the open confessions and the tacit admissions, you find that, apart from these anxieties and annoyances, the kind of life which riches and honors bring is not a satisfactory life—its inside differs immensely from its outside. In candid moments the "social tread-mill" is complained of by those who nevertheless think themselves compelled to keep up its monotonous round. As every one may see, fashionable life is passed, not in being happy, but in playing at being happy. And yet the manifest corollary is not drawn by those engaged in this life.

To an outsider it is obvious that the benefits obtained by the regulative classes of our day, through the existing form of social organization, are full of disguised evils; and that this undue wealth which makes possible the passing of idle lives brings dissatisfactions in place of the satisfactions expected. Just as in feudal times the appliances for safety were the accompaniments to a social state that brought a more than equivalent danger; so, now, the excess of aids to pleasure among the rich is the accompaniment of a social state that brings a counterbalancing displeasure. The gratifications reached by those who make the pursuit of gratifications a business, dwindle to a minimum; while the trouble, and weariness, and vexation, and jealousy, and disappointment, rise to a maximum. That this is an inevitable result any one may see who studies the psychology of the matter. The pleasure-hunting life fails for the reason that it leaves large parts of the nature unexercised: it neglects the satisfactions gained by successful activity, and there is missing from it the serene consciousness of services rendered to others. Egoistic enjoyments, continuously pursued, pall, because the appetites for them are satiated in times much shorter than our waking lives give us: leaving times that are either empty or spent in efforts to get enjoyment after desire has ceased. They pall also from the want of that broad contrast which arises when a moiety of life is actively occupied. These negative causes of dissatisfaction are joined with the positive cause indicated—the absence of that content gained by successful achievement. One of the most massive and enduring gratifications is the sense of personal worth, ever afresh demonstrating itself to consciousness by effectual action; and an idle life is balked of its hopes partly because it lacks this. Lastly, the implied absence of altruistic activities, or of activities felt to be in some way serviceable to others, brings kindred evils —an absence of certain positive pleasures of a high order, not easily exhausted, and a further falling back on egoistic pleasures, again tending toward satiety. And all this, with its resulting weariness and discontent, we may trace to a social organization under which there comes to the regulating classes a share of produce great enough to make possible large accumulations that support useless descendants.

The bias of the wealthy in favor of arrangements apparently so conducive to their comforts and pleasures, while it shuts out the perception of these indirect penalties brought round on them by their seeming advantages, also shuts out the perception that there is any thing mean in being a useless consumer of things which others produce. Contrariwise, there still survives, though in a weaker form, the belief that it is honorable to do nothing but seek enjoyments, and relatively dishonorable to pass life in supplying others with the means to enjoyment. In this, as in other things, our temporary state brings a temporary standard of honor appropriate to it; and the accompanying sentiments and ideas exclude the conception of a state in which what is now thought admirable will be thought disgraceful. Yet it needs only, as before, to aid imagination by studying other times and other societies, remote in nature from our own, to see at least the possibility of this. When we contrast the feeling of the Feejeeans, among whom a man has a restless ambition to be acknowledged as a murderer, with the feeling among civilized races, who shrink with horror from a murderer, we get undeniable proof that men in one social state pride themselves in characters and deeds elsewhere held in the greatest detestation. Seeing which, we may infer that, just as the Feejeeans, believing in the honorableness of murder, are regarded by us with astonishment; so those of our own day who pride themselves in consuming much and producing nothing, and who care little for the well-being of their society so long as it supplies them with good dinners, soft beds, and pleasant lounging-places, may be regarded with astonishment by men of times to come, living under higher social forms. Nay, we may see not merely the possibility of such a change in sentiment, but the probability. Observe first the feeling still extant in China, where the honorableness of doing nothing, more strongly held than here, makes the wealthy wear their nails so long that they have to be tied back out of the way, and makes the ladies submit to prolonged tortures that their crushed feet may show their incapacity for work. Next, remember that, in generations gone by, both here and on the Continent, the disgracefulness of trade was an article of faith among the upper classes, maintained very strenuously. Now, mark how members of the landed class are going into business, and even sons of peers becoming professional men and merchants; and observe among the wealthy the feeling that men of their order have public duties to perform, and that the absolutely idle among them are blameworthy. Clearly, then, we have grounds for inferring that, along with the progress to a regulative organization higher than the present, there will be a change of the kind indicated in the conception of honor. It will become a matter of wonder that there should ever have existed those who thought it admirable to enjoy without working, at the expense of others who worked without enjoying.

But the temporarily adapted mental state of the ruling and employing classes keeps out, more or less effectually, thoughts and feelings of these kinds. Habituated from childhood to the forms of subordination at present existing—regarding these as parts of a natural and permanent order—finding satisfaction in supremacy, and conveniences in the possession of authority; the regulators of all kinds remain unconscious that this system, made necessary as it is by the defects of existing human nature, brings round penalties on themselves as well as on those subordinate to them, and that its pervading theory of life is as mistaken as it is ignoble.

Enough has been said to show that from the class-bias arise further obstacles to right thinking in sociology. As a part of some general division of a community, and again as a part of some special subdivision, the citizen acquires adapted feelings and ideas which inevitably influence his conclusions about public affairs. They affect alike his conceptions of the past, his interpretations of the present, his anticipations of the future.

Members of the regulated classes, kept in relations more or less antagonistic with the classes regulating them, are thereby hindered from seeing the need for, and benefits of, this organization which seems the cause of their grievances; they are at the same time hindered from seeing the need for, and benefits of, the harsher forms of industrial regulation that existed during past times; and they are also hindered from seeing that the improved industrial organizations of the future can come only through improvements in their own natures. On the other hand, members of the regulating classes, while partially blinded to the facts that the defects of the working-classes are the defects of natures like their own placed under different conditions, and that the existing system is defensible, not for its convenience to themselves, but as being the best now practicable for the community at large, are also partially blinded to the vices of past social arrangements, and to the badness of those who in past social systems used class-power less mercifully than it is used now; while they have difficulty in seeing that the present social order, like past social orders, is but transitory, and that the regulating classes of the future may have, with diminished power, increased happiness.

Unfortunately for the Social Science, the class-bias, like the bias of patriotism, is in a degree needful for social preservation. It is like in this, too, that escape from its influence is often only effected by an effort that carries belief to an opposite extreme—changing approval into a disapproval that is entire instead of partial. Hence, in the one case, as in the other, we must infer that the resulting obstacle to well-balanced conclusions can become less only as social evolution becomes greater.

THE BORERS OF THE SEA.

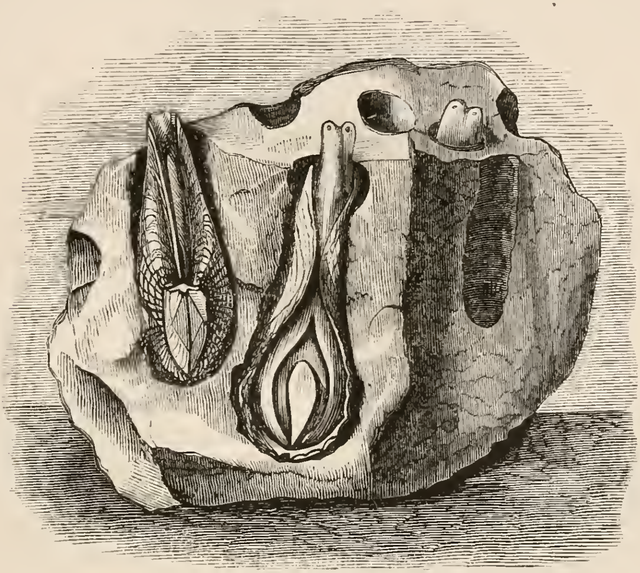
MANY stories are current as to how inventors have borrowed or stolen their ideas from Nature, and there has been much ingenious discussion as to whether hints thus appropriated are properly patentable. Boring is an example of natural processes that have been thus used by art, and it is remarkable that the lowest creatures are the most skilful mechanics in this particular. An eminent living inventor, who has made a fortune out of a patent auger, hit upon the method followed by the most successful insects which bore into hard wood. And so we are assured that the celebrated engineer Brunel, in constructing the Thames Tunnel, but imitated the shell-lined burrow of the *Teredo navalis*, or Ship-worm. This mollusk in shape resembles a worm, and surrounds itself with a shell open at both ends. From the mouth it can protrude its short foot, and the other extremity of its body; the "tail" is bifurcated, one prong being the inspirator and the other the expirator tube of the siphon which constitutes the animal's nutritive apparatus.

It has long been a subject of controversy among naturalists how the Ship-worm and other mollusks of the same family bore their way into the rocks and timbers which they penetrate. As regards the Pholades, for instance, Mr. Robertson, who kept these animals alive in their chalky burrows, and studied their habits with the closest attention, found that when burrowing they make a half-revolution of their shell to the right, and then back to the left, after the manner of a carpenter using a brad-awl. The Pholas is a bivalve, club-shaped, and the outer surface of its shell is covered with small teeth in curves, and resembling the face of a rasp. These teeth would naturally seem well suited for the purpose of boring, yet all naturalists are not agreed on this point. Thus, some hold that the animal secretes an acid solvent, which causes the material in which it is burrowing to decay. Then only is it that, securing itself with its sucker-like foot, it works itself from right to left, and *vice versa*, to widen the passage. But Mr. Gwynn Jeffreys, as stated in the December number of The Popular Science Monthly, is of opinion that the foot, which he says is charged with siliceous particles, is the true boring apparatus of all the conchifera, and acts like the leaden wheel of the lapidary.

The history of the development of the *Teredo* is thus given by M.

de Quatrefages: "The larva, which is at first almost spherical and entirely covered with vibratile cilia, may be compared to a very minute hedgehog, in which every spine acts as a natatory organ. It swims in all directions with extreme agility, and this first state continues

Fig. 1.



Rock perforated by Pholades.

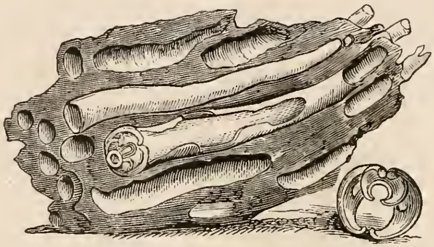
about a day and a half. Toward the end of this time the external skin bursts, and, after being incrusted with calcareous salts, becomes a shell, which is at first oval, then triangular, and at last very nearly spherical. While the shell is being formed, the vibratile cilia disappear, but the little animal is not on that account condemned to inactivity. In proportion as the external cilia diminish, we observe that another equally ciliated organ becomes developed, which widens and extends in such a manner as to form a large collar or ruff margined with fringes. This new organ of locomotion may be entirely concealed within the shell, or may be extended from it, and acts in the manner of the paddle-wheel of a steamboat.

"By means of this apparatus the young larva continues to swim with as much facility as in its earlier age; but it now, moreover, acquires another organ, a sort of fleshy foot, which can be extended and contracted at will. It has also organs of hearing similar to those of several mollusks, and eyes analogous to those of certain annelids." The last metamorphosis is when the Teredo takes its worm-shape, and is ready to commence its boring operations.

The Teredo is supposed to have been originally a native of tropical or semitropical seas, though now it is found in high latitudes. It does not appear to have been known to the Greeks or Romans, or at least its ravages in ancient times could not have been very great, else the unsheathed hulls of Greek and Roman vessels would have been perforated. The Pholas penetrates stone as well as wood, but the Teredo loves most to burrow into timber.

The damage done to submerged timbers by the Teredo is enormous.

Fig. 2.



Timber honey-combed by the Teredo.

It once threatened the dikes of Holland with destruction. A portion of the pier at Yarmouth was so honey-combed with perforations that it might easily be crushed between the hands as though it were paper, the partition between the various tubes being in many places as thin as parchment. A piece broken off this pier, and measuring about 7 by 11 inches, weighed less than four ounces, including the shelly lining of the tubes. In the space of 40 days a piece of deal was fairly riddled by these borers, and Wood, in his "Natural History," gives an instance of their attacking a floating block of oak. This block had a large iron bolt passing through its centre, the rusting of which preserved the timber for a small space all around from the attacks of the borers. But all the block not so protected was honey-combed.

The Ship-worm always makes its perforations in the direction of the grain of the timber, except where a knot, or the shell of another Teredo, or hindrance of any kind is met with, and then it takes a turn according to circumstances. The animal begins to bore long before it has reached its full size, and it grows within the cavity which it makes. When taken out of the tube the Ship-worm is found to be a long, grayish-white animal, about one foot long and half an inch thick, with rounded head and forked tail. The Giant Teredo of Sumatra attains the length of six feet, and a diameter of three inches. This animal, however, differs from the Ship-worm in this, that it does not penetrate timber, but only burrows into the hardened mud of the sea-bed.

The use of copper-sheathing to protect ships from the Ship-worm is so well known that it need but be simply referred to here. It is not perhaps so generally known that, if timber be driven full of iron nails, the same object is attained. Another method of protecting wood-work consists in forcing into its pores a solution of corrosive sublimate. The only objection to this method is its great cost. Quatrefages, however, asserts that one twenty-millionth part of corrosive sublimate is enough to destroy all the young Ship-worms in two hours. He, therefore, proposes that ships should be cleared of this fearful pest by being taken into a closed dock, into which a few handfuls of corrosive sublimate should be thrown and well mixed with the water. The salts of copper and lead have a similar effect, but do not act so instantaneously.

The Teredo does not perforate rock, but the Pholas acts an important part in bringing about geological changes, owing to his habit of boring rocks. There is no doubt that the chalk-cliffs of England are first tunnelled by the Pholades, and then gradually destroyed by the waves of the sea.

Of the Date-shell, another very interesting borer, Wood gives the following account: "It is truly a wonderful little shell. Some of the hardest stones and stoutest shells are found pierced by hundreds of these curious beings, which seem to have one prevailing instinct, namely, to bore their way through every thing. Onward, ever onward, seems to be the law of their existence, and most thoroughly do they carry it out. They care little for obstacles, and, if one of their own kind happens to cross their path, they quietly proceed with their work, and drive their tunnel completely through the body of their companion."

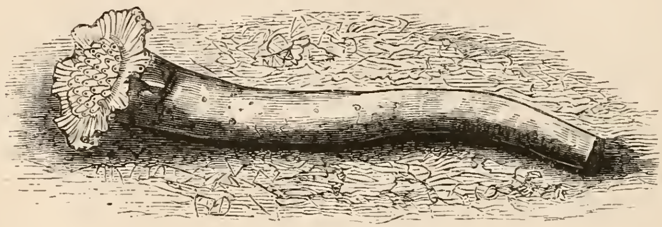
Of the *Saxicava rugosa*, another borer, Wood gives this description: "It is a flattish bivalve, symmetrical in shape when young, but oblong when old. It burrows as rapidly as the *Lithodomus*, and into rock of adamantine density. Sometimes it bores into corals, frequently into limestone, and often into shells, which it penetrates as deeply as the Date-shell. Some of the enormous stones employed in building the Plymouth Breakwater are now much wasted by the holes made in them by the *Saxicava*." Like the Date-shell, too, this animal runs its tunnels at every angle, and turns out of its course for no consideration whatever.

The Razor-shell makes a burrow in the sand, and there lives with its siphon, or recurved food-tube, appearing just above the mouth of the burrow. It may often be seen "spouting," or sending forth small jets of water from its hiding-place in the sand after the tide has retreated. On examining the spot cautiously—for the creature is somewhat shy—two round holes in the sand, answering to the two fringed openings of the Razor-shell's siphon, will be seen, resembling a key-hole, and each large enough to admit a common goose-quill. But, if the animal be approached rudely, or if the finger be placed on the openings, the mollusk disappears deep in the burrow. The Razor-shell is possessed of a very muscular "foot," as it is called, but it might as well be named a hand or a *tongue*. By means of this organ, which they elongate or contract at pleasure, the animals are enabled to burrow and to go "up and down stairs" with great rapidity. It requires dexterous management to capture the Razor-shell alive. When they are wanted for food or for bait, the usual plan is to shoot into the sand, alongside of a "spout," a hooked iron rod, which must be at once pulled out again obliquely, so as to fetch the shell.

A better way is to drop a little salt on its tail, or at least on its siphon-orifices. If this be done, the animal will rise partly out of its burrow—for it hates undiluted chloride of sodium—and may then be captured, if you be quick. But, if you should fail to seize the creature at the first attempt, in vain would you pour salt in the burrow; the mollusk now sees the artifice, and is not to be imposed upon a second time.

The *Aspergillum*, or Watering-pot Shell, derives its name from its perforated disk, which much resembles the snout of a watering-pot. This animal burrows into sand or bores into stone, wood, or thick shells.

Fig. 3.



Aspergillum, or Watering-pot.

When in its burrow, its narrow end, containing the openings of its siphon, protrudes. To the same group belongs the Flask-shell, which perforates shells of every kind, attaching them to itself by means of some natural cement. It thus often constructs around itself a casing like a flask, and hence its name.

We will close this notice of the Borers of the Sea with some account of the *Mya arenaria*, or Gaper-shell, which burrows into sand, and which derives its name, gaper, from the fact that its bivalve-shell gapes, to allow its long, stout tube to protrude. "It inhabits sandy and muddy shores," says Wood, "and, to an inexperienced eye, is quite invisible. The shell itself, together with the actual body of the mollusk, is hidden deeply in the mud, seldom less than three inches, and generally eleven or twelve inches from the surface. In this position it would be unable to respire were it not for the elongated tube, which projects through the mud into the water, and just permits the extremities of the siphons to show themselves, surrounded by the little radiating tentacles which betray them to the experienced shell-hunter."

ON THE CAUSES WHICH OPERATE TO CREATE SCIENTIFIC MEN.

By FRANCIS GALTON.

ON more than one occasion I have maintained that intellectual ability is transmitted by inheritance; and, in a memoir published last year in the "Proceedings of the Royal Society," I endeavored to explain what ought to be understood by that word "inheritance." Two points were especially urged; the first, that each personality originates in a small selection out of a large batch of wonderfully varied elements, which were all latent and competing; and, secondly, that these batches, and not the persons derived from them, form the principal successive stages in the line of direct descent. Hence follows the paradoxical conclusion that the child must not be looked upon as directly descended from his own parents. His true relation to them is both circuitous and complicated, but admits of being easily expressed by an illustration. Suppose an independant nation, A, to have been formed by colonists from two other similarly constituted nations, B and C; then the relation borne by the *representative government* of A to that of B and of C is approximately similar to what I suppose to be the relation of a child to each of his parents. But the existence of a slender strain of direct descent is shown by the fact of acquired habits being occasionally transmitted. We must therefore amend our simile by supposing the members of the governments of B and C to have the privilege of making emigration easy and profitable to their constituents, and also, perhaps, the governments themselves to have the power of nominating a few individuals to seats in the Legislative Council of A.

It appears to me of the highest importance, in discussing heredity, to bear the character of this devious and imperfect connection distinctly in mind. It shows what results we may and may not expect. For instance, if B and C contain a large variety of social elements, it would be impossible, without a very accurate knowledge of them and of the conditions of selection, to predict the characters of their future governments. Still less would it be possible to predict that of A. But if the social elements of B and C were alike, and in each case simple, such as might be found in pastoral tribes, then the character of their governments and that of A could be predicted with some certainty. The former supposition illustrates what must occur when the breed of the parents is mongrel; the latter, when it is pure. Now, no wild or domestic animal is so mongrel as man, especially as regards his mental faculties; therefore, we cannot expect to find an invariable resemblance between the faculties of children and those of their parents. All that could be expected on the hypothesis of strict inheritance we do find; that is, occasional startling resemblances, and much more frequently partial ones. From this we have a right to argue that if the breed of men were more pure, the intellectual resemblance of child to parent would be as strict as in the forms of the equally pure breeds of our domestic animals.

I propose to refer in this article to a volume written by M. de Candolle,[1] son of the late famous botanist, and himself a botanist, and scientific man of high reputation, in which my name is frequently referred to and used as a foil to set off his own conclusions. The author maintains that minute intellectual peculiarities do not go by descent, and that I have overstated the influence of heredity, since social causes, which he analyzes in a most instructive manner, are much more important. This may or may not be the case; but I am anxious to point out that the author contradicts himself, and that expressions continually escape from his pen at variance with his general conclusions. Thus he allows (p. 195) that, in the production of men of the highest scientific rank, the influence of race is superior to all others ("prime les autres en importance"); that (p. 268) there is a yet greater difference between families of the same race than between the races themselves; and that (p. 326), since most, and probably all, mental qualities are connected with structure, and as the latter is certainly inherited, the former must be so as well. Consequently, I propose to consider M. de Candolle as having been my ally against his will, notwithstanding all he may have said to the contrary.

The most valuable part of his investigation is this: What are the social conditions most likely to produce scientific investigators, irrespective of natural ability, and *a fortiori*, irrespective of theories of heredity? This is, necessarily, a one-sided inquiry, just as an inquiry would be that treated of natural gifts alone. But, for all that, it admits of being complete in itself, because it is based on statistics which afford well-known means of disentangling the effect of one out of many groups of contemporaneous influences. The author, however, continually trespasses on hereditary questions, without, as it appears to me, any adequate basis of fact, since he has collected next to nothing about the relatives of the people upon whom all his statistics are founded. The book is also so unfortunately deficient in method, that the author's views on any point have to be sought for in passages variously scattered; but it is full of original and suggestive ideas, which deserve to have been somewhat more precisely thought out and much more compendiously stated.

Its scheme is, to analyze the conditions of social and political life under which the principal men of science were severally living at the

[1] "*Histoire des Sciences et des Savants depuis deux Siècles.*" Par Alphonse de Candolle (Membre Corr. de l'Acad. Sciences, Paris; Foreign Member, Royal Soc., etc.). Geneva, 1873.

four epochs 1750, 1789, 1829, and 1869. The list of names upon which he depends is that of the foreign members of the three great scientific societies of Europe—namely, the French Academy, the Royal Society, and the Academy of Berlin—in each case about fifty in number. There is a yet stricter selection on the part of the foreign associates of the French Academy, who number only eight at a time, and of whom there have been only ninety-two[1] in the last two hundred years. It is remarkable that we find in this very select list four cases of father and son—namely, a Bernoulli and two of his sons, the two Eulers, and the two Herschels.

From an examination of these lists the author draws a large variety of interesting deductions. He traces the nationalities and the geographical distribution of the distinguished men of science, and compares the social conditions under which they lived. He finds them to be confined to a triangular slice of Europe, of which middle Italy forms the blunt apex, and a line connecting Sweden and Scotland forms the base; and then he shows that, out of a list of eighteen different influences favorable to science, such as liberty of publication, tolerant church, and temperate climate, a large majority were found in the triangular space in question, and there alone. The different nations vary at the different epochs in their scientific productiveness;[2] and he elaborately shows how closely the variation depends on some

[1] List of the ninety-two foreign associates of the French Academy (three names of no scientific importance having been omitted, who were elected in early days—these are: Lord Pembroke, 1710; Duc d'Escalone, 1715; and Prince Lœwenstein-Wertheim, 1766). The names are arranged in the order of their election, and a dash (—) divides those elected before and after the year 1800:

Denmark: None.—Œrsted.

England: Newton, Sloane (Sir Hans), Halley, Folkes, Bradley, Hales, Macclesfield (Earl), Morton (Earl), Pringle, Hunter, Priestley, Banks, Black.—Maskelyne, Cavendish, Jenner, Watt, Davy, Wollaston, Young, Dalton, Brown (Robert), Faraday, Brewster, Herschel (Sir John), Owen, Murchison.

Germany (Ancient Confederation): Rœmer, Leibnitz, Tchirnhausen (de), Wolff, Margraff, Herschel (Sir William).—Pallas, Klaproth, Humboldt (de), Werner, Gauss, Olbers, Blumenbach, Buch (de), Bessel, Jacobi, Tiedemann, Mitscherlik, Lejeune-Dirichlet, Ehrenberg, Liebig, Wöhler, Kummer.

Holland: Huyghens, Hartsoeker, Ruysch, Boerhaave, Van Swieten, Camper.—None.

Italy: Guglielmini, Cassini (Dom), Viviani, Poli, Bianchini, Marsigli, Manfredi, Morgagni, Cervi, Poleni, La Grange (de).—Volta, Scarpa, Piazzi, Plana.

Poland: Jablonowski.—None.

Russia: Euler (the son).—None.

Sweden: Linnæus, Bergmann, Wargentin.—Berzelius.

Switzerland: Bernoulli (Jacques), Bernoulli (Jean), De Crousaz, Bernoulli (Daniel), Haller (de), Euler (Léonard), Tronchin, Bernoulli (Jean II.), Bonnet (Charles), Saussure (Hor. Ben. de).—Candolle (Aug. Pyr. de), Rive (de la).

United States: Franklin.—Rumford.

[2] The author's tables of the scientific productiveness per million, of different nations at different times, are affected by a serious statistical error. He should have reckoned per million of men above fifty, instead of the population generally In a rapidly-increas-

or other of the eighteen influences becoming favorable or unfavorable. The author, himself descended from the Huguenots, lays just stress on the influence of religious refugees, whose traditions were to work in a disinterested way for the public good, and at the same time to avoid politics. The refugees rarely had their property in land, of which the oversight occupies time, but in movable securities; thus they had leisure for work. Then, again, as they were debarred from local politics, the ambition, especially of those who had taken refuge in small countries, was to earn the approval of the enlightened men all over Europe, and this could most easily be effected by doing good work in science. Out of the ninety-two foreign associates of the French Academy, no less than ten were descended from religious refugees, usually in the third or fourth generation. Switzerland had eight out of the ten, and we may thence easily gather how enormously she is indebted to the infusion of immigrant blood. Similarly, the only two American associates—Franklin and Rumford—were descended from Puritans.

The blighting effect of dogmatism upon scientific investigation is shown both in Catholic and Protestant countries. The Catholics are the more dogmatic of the two, and they supply, in proportion to their population, less than one-quarter as many of the foremost scientific men as the Protestants. There is not a single English or Irish Catholic among the ninety-two French foreign associates. Austria contributes no name, and the rest of Catholic Germany is almost barren. In Switzerland, the scientific productiveness of the Catholics is only $\frac{1}{26}$ that of the Protestants. Again, the Catholic missionaries have done nothing for science, notwithstanding their splendid opportunities. In past days, when they were absolute masters of vast countries, as Paraguay and the Philippines, the smallest encouragement and instruction given at the college of the Propaganda to young and apt missionaries would have enriched Rome with collections of natural history. If any city more than others deserved to have the finest botanical garden and richest herbarium, it is Rome; but she has scarcely any thing to show.

The most notable instance of the repressive force of Protestant dogmatism is to be found in the history of the republic of Geneva. During nearly 200 years (1535 to 1725) its laity as well as clergy were absolutely subject to the principles of the early Reformers. Instruction was imposed on them; nearly every citizen was made to pass through the college, and many attended special courses at the Academy, yet, during the whole of that period, not a single Genevese distinguished himself in science. Then occurred the wane of the Calvinist authority, between 1720 and 1735. Social life and education be-

ing country like England, the proportion of the youthful population to those of an age sufficient to enable them to become distinguished is double what it is in France, where population is stationary; and injustice may be done by these tables to England in something like that proportion. They require entire reconstruction.

came penetrated with liberal ideas;[1] and, since 1730, the date of the first election of a Genevese to an important foreign scientific society—our own Royal Society—Geneva has never ceased to produce mathematicians, physicists, and naturalists, in a number wholly out of proportion to her small population.

The author argues from these and similar cases that it is not so much the character of the dogma taught that is blighting to science as the dogmatic habit in education. It is the evil custom of continually telling young people that it is improper to occupy their minds about such and such things, and to be curious, that makes them timid and indifferent. Curiosity about realities, not about fictions of the imagination, is the motive power of scientific discovery, and it must be backed up by a frank and fearless spirit. M. de Candolle, in spite of his anti-heredity declarations, enunciates an advanced pro-heredity opinion well worthy of note. He says it is known that birds originally tame, when found on a desolate island, soon acquire a fear of man, and transmit that fear as an instinctive habit to their descendants. Hence, we might expect a population, reared for many generations under a dogmatic creed, to become congenitally indisposed to look truth in the face, and to be timid in intellectual inquiry.

Can, then, religion and science march in harmony? It is true that their methods are very different; the religious man is attached by his heart to his religion, and cannot endure to hear its truth discussed, and he fears scientific discoveries which might, in some slight way, discredit what he holds more important than all the rest. The scientific man seeks truth regardless of consequences; he balances probabilities, and inclines temporarily to that opinion which has most probabilities in its favor, ready to abandon it the moment the balance shifts, and the evidence in favor of a new hypothesis may prevail. These, indeed, are radical differences, but the two characters have one powerful element in common. Neither the religious nor the scientific man will consent to sacrifice his opinions to material gain, to political ends, nor to pleasure. Both agree in the love of intellectual pursuits, and in the practice of a simple, regular, and laborious life, and both work in a disinterested way for the public good. A strong evidence of this fundamental agreement is found in the number of sons of clergymen who have distinguished themselves as scientific investigators; it is so large that we must deplore the void in the ranks of science caused by the celibacy of the Catholic clergy. If Protestant ministers, like them, had never married, Berzelius, Euler, Linnæus, and Wollaston, would never have been born. But to revert to what we were speaking about. There are some six different objects in the pur-

[1] In 1735, public opinion had become so tolerant that it was enacted that candidates for the ministry should no longer be required to make a declaration of faith, but simply to promise to teach and preach conformably to the Bible and to the light of their own consciences (p. 204).

suit of which most men spend their energies: three of them refer to self—namely, property, pleasure, and political advancement; the other three imply devotion to ideas—namely, religion, science, and art. Without a doubt, as M. de Candolle says, the former three occupy one half of the moral sphere of the human character, and the latter three the other.

It appears that the men distinguished in science have usually been born in small towns, and educated by imperfect teachers, who made the boys think for themselves. Nothing is brought out more clearly in the work than that the first desideratum in scientific education is to stimulate curiosity and the observation of real things, and that too much encouragement of the receptive faculty is a serious error. The author justly laments that the art of observation is not only untaught, but is actually discouraged by modern education. Children are apt and eager to observe, but, instead of encouraging and regulating their instincts, the school-masters keep them occupied solely on internal ideas, such as grammar, the vocabularies of different languages, arithmetic, history, and poetry. They learn about the living world which surrounds them out of books, and not through their own eyes. One of the reformations he proposes is, to make much more use of drawing as a means of careful observation, compelling the pupils to draw quickly the object they have to describe, from memory, after a short period allowed for its examination. He is a strong advocate for the encouragement of a class of scientific sinecurists like the non-working fellows of our colleges, who should have leisure to investigate, and not be pestered by the petty mechanical work of continual teaching and examining. Science has lost much by the suppression of the ecclesiastical sinecures at the time of the French Revolution, for there used to be many abbés on the lists of foreign scientific members, but they have now almost wholly disappeared. The modern ideas of democracy are adverse to places to which definite work is not attached, and from which definite results do not regularly flow. This principle is a wise one for the mass of mankind; but how utterly misplaced when applied to those who have the zeal for investigation, and who work best when left quite alone!

There is a curious chapter on the probability of English becoming the dominant language of the world in fifty or a hundred years, and being the one into which the more important scientific publications of all nations will, as a matter of course, be translated. It is not only that the English-speaking population will outnumber the German and the French, as these now outnumber the Dutch and the Swedish, but that the language has peculiar merits, through its relationship with both the Latin and the Teutonic tongues. It also seems that, in families where German and French are originally spoken, French always drives out the German on account of its superior brevity. When people are in a hurry, and want to say something quickly, it is more easily said in French than in German. Precisely in the same way English beats French. Our sentences don't even require to be finished in order to be understood, because the leading ideas come out first; but, as for old-fashioned tongues, their roundabout construction would be perfectly intolerable. Fancy languages, like Latin and Greek, in which people did not say "yes" or "no." M. de Candolle is very disrespectful to classical Latin. He says that one must have gone through the schools not to be impressed by its ridiculous construction. Translate an ode of Horace literally to an unlettered artisan, keeping each word in its place, and it will produce the effect upon him of a building in which the hall-door was up in the third story. It is no longer a possible language, even in poetry.

I have only space for one more of the many subjects touched upon in his book—that of acquired habits being transmitted hereditarily—and which has also formed the subject of a recent essay by Dr. Carpenter. That some acquired habits in dogs are transmitted appears certain, but the number is very small, and we have no idea of the cause of their limitation. With man they are fewer still; indeed, it is difficult to point out any one, to the acceptance of which some objection may not be offered. Both M. de Candolle and Dr. Carpenter have spoken of the idiocy and other forms of nervous disorder which, beyond all doubt, afflict the children of drunkards. Here, then, appears an instance based on thousands of observations at lunatic asylums and elsewhere, in which an acquired habit of drunkenness, which ruins the will and nerves of the parent, appears to be transmitted hereditarily to the child. For my own part, I hesitate in drawing this conclusion, because there is a simpler reason. The fluids in an habitual drunkard's body, and all the secretions, are tainted with alcohol; consequently the unborn child of such a woman must be an habitual drunkard also. The unfortunate infant takes its dram by diffusion, and is compulsorily intoxicated from its earliest existence. What wonder that its constitution is ruined, and that it is born with unstrung nerves, or idiotic or insane? And just the same influence might be expected to poison the reproductive elements of either sex. I am also informed, but have not yet such data as I could wish, that children of recent teetotallers who were formerly drunkards are born healthy. If this be really the case, it seems to settle the question, and to show that we must not rely upon the above-mentioned facts as evidence of a once-acquired habit being hereditarily transmitted.—*Fortnightly Review.*

THE SHERMAN ASTRONOMICAL EXPEDITION.

By EMMA M. CONVERSE.

SCIENTIFIC observers have long seen the importance of securing a position elevated above the fogs and impurities of the atmosphere at the sea-level, for the purpose of making more accurate astronomical and meteorological observations. Accordingly, Prof. Peirce, the Superintendent of the Coast Survey, petitioned Congress for means to carry out such an undertaking. Congress made an appropriation of $2,000 for this special object, independent of the geographical and topographical constants of the station.

Sherman, in Wyoming, situated on the highest point of the Union Pacific Railway, and on the Rocky Mountain range, was agreed upon as an eligible and convenient locality for the scene of operations; and the months of June, July, and August, 1872, were devoted to the work.

The party consisted of General R. D. Cutts, an experienced officer of the Coast Survey, who had charge of the expedition, Assistant Mosman, Aid Colonna, Prof. Young, Prof. Emerson, and Mr. Mead, of Dartmouth College. There were also a photographer, a mechanician, and two servants. The party had, as an escort, about a dozen soldiers from Fort Russell, at Cheyenne, who assisted in keeping the hourly series of meteorological observations, and were detailed to serve as a protection from possible attacks of hostile Indians.

It was not until July that the members from Dartmouth College were able to join the expedition. The trustees of the college had loaned their valuable telescope for the occasion. It has an aperture of $9\frac{4}{10}$ inches, and a focal length of 12 feet, with clock-work, and the usual accompaniments, and is fitted with an automatic spectroscope, having a dispersive power of 13 prisms. This telescope is one of the best in the country in optical perfection, and in convenience and handiness of mounting.

The summit of a slight elevation was chosen as an eligible locality for occupation. It was a short distance from the railroad-station, and about 40 or 50 feet above the track. Three shanties of rough boards were erected as observatories, one for the transit instrument, one for the meteorological apparatus, and one for the equatorial telescope. The altitude of the observatory is 8,300 feet above the level of the sea, the latitude a little more than 44°, and the longitude about 28° west from Washington.

It was thought that Sherman combined unusual facilities for accomplishing the desired object of the expedition, which was to test the advantages of a great elevation upon astronomic, and especially spectroscopic, work. The currents, impurities, and reflective power of the atmosphere at the sea-level, interfere greatly with studies of this kind, while an elevation of 8,000 feet leaves more than a fourth of the atmosphere below it. The situation was one of remarkable natural beauty. On the east there was little to mark the altitude except the rocky soil and scanty vegetation; on the north there were picturesque piles of granite; on the north-west lay the Laramie Hills; from the north-west to the south towered the mountain-peaks, many of them covered with perpetual snow. Long's Peak and Gray's Peak were 60 miles away at the south; the great mass of Medicine Bow lay at the west, and between them, over the lower ridges, rose some of the high mountains of the Colorado parks.

The party being located, and all arrangements for observation being made as systematic as possible, work was carried on during the summer months in earnest, and attended with valuable results for the initiatory movement of a work of such magnitude. The weather proved to be unusually unfavorable. An old trapper, who had lived among the mountains for twenty years, said that the amount of cloudy and rainy weather was uncommon for the season. With the exception of a week, when every night and a greater part of ever day were fine, clear nights were rare, and clear days less so. There were but two afternoons when work upon the sun could be kept up from noon till sunset, though there were more than twenty cloudless mornings during the same time. The enormous snow-fall of the preceding winter accounted for the unusual weather-condition of the locality, and the snow, in the middle of July, was still lying to the depths of eight feet on the plateau at the base of the Medicine Bow Mount.

Notwithstanding these drawbacks, valuable scientific results were obtained in five different departments of observation, geographical, meteorological, telescopic, spectroscopic, and magnetic.

The geographical position of the station was completely determined, its longitude being obtained by telegraphic communication with Salt Lake City. It will, therefore, be for the future a reference-point and base for the numerous surveys which are being made in that part of the country.

A complete hourly meteorological record was obtained for nearly the whole of the months of June, July, and August, which, from the important position of the station, cannot fail to be of great interest and value.

The telescopic observations were full of promise for the result of future and more thorough work in that department. When the sky was unclouded the atmosphere possessed the most ethereal transparency. At night, myriads of stars invisible at lower elevations were plainly discernible. Nearly all the seventh-magnitude stars of the British Association Catalogue were clearly visible to the naked eye. Prof. Young, to whose report we are indebted for the facts recorded in this article, says that, in the quadrilateral forming the bowl of the "Dipper," he could see distinctly nine stars, with glimpses of one or two more, while at Hanover he could only perceive the three brightest of them. The power of the telescope was correspondingly increased, so that an instrument of $9\frac{4}{10}$ inches of aperture was as effective as one with 12 inches at the sea-level. Some views of Saturn were exquisitely beautiful. The inner satellites, the details and markings of the rings, especially a dark stripe upon the outer ring, were clearly seen under powers ranging from 500 to 1,200. Besides the increase of the range of the instrument, the air was vastly more steady, and faint objects much more clearly defined.

The advantage was still greater in the careful spectroscopic observations that were made. Prof. Young had drawn up at Hanover a catalogue of 103 bright lines in the spectrum of the chromosphere; at Sherman the number was extended to 273, while, at moments of unusual solar disturbance, there were glimpses of at least as many more. Sulphur, strontium, and cerium, are almost certainly proved to be constituents of the solar atmosphere, and zinc, erbium, and didymium are strongly indicated. It was hoped that at the base of the chromosphere there might be seen the reversal of the dark lines of the spectrum, which is so wondrously beautiful at the commencement and close of a total solar eclipse. But in this hope the observers were disappointed; the appearance, at the distance of 1″ or 15″ from the edge of the photosphere, giving a spectrum principally continuous, most of the dark lines vanishing or being much weakened. This result confirms the observations of Secchi, who reports at the edge of the sun a layer giving a continuous spectrum.

Curious observations were made upon the spectra of sun-spots, and a catalogue was made of 155 lines more or less affected, either greatly widened or weakened, or reversed. A number of bright lines were found in the spectrum of the nucleus, and some peculiarly shaded, as if they were the product of a combination of elements which, from the reduced temperature over the spots, had been able to exercise their chemical affinities.

Many solar eruptions were watched moving with velocities varying from 150 to 250 miles per second, and pouring forth their whirlwinds and torrents of ejected gas through the molten atmosphere. The most interesting eruption was visible on the surface of the sun itself in the vicinity of a large spot.

The magnetic observations were as satisfactory as any that were made, and yet prove that, although our greatest magnetic storms are only remotely connected with solar influence, every solar paroxysm has a direct and immediate effect upon terrestrial magnetism. On the 3d and 5th of August there were violent paroxysms of solar eruption. At just the minute these eruptions took place, the record of the vertical Magnetic Force shows marked and sudden magnetic impulses, a peculiar shuddering of the magnetic needle for that very time. The photographic copies of the vertical Force Curve at Greenwich and

Stonyhurst show marked and characteristic disturbances at the corresponding points, which, allowing for the difference in longitude, were the very moments of time when the solar disturbances were watched at Sherman.

The work of the last summer accomplished by the Sherman Astronomical Expedition points clearly to the inference that a great national observatory should be established without loss of time, in that position on the American Continent most favorable to astronomical observation. Sherman is evidently not the place, on account of weather-conditions, but some mountain-station must be found adapted for the purpose, far above the fogs and impurities of the sea-level. A telescope, the best and largest that scientific resources can furnish, and a corps of observers devoted to the work, must be established on this permanent locality. Then, from this high point, sun, planets, stars, nebulæ, comets, and meteors, may be attacked by observers armed with the most effectual scientific weapons, until from the depths of infinite space come answers to some of the great problems that are puzzling the brains of thoughtful students of celestial mysteries.

A recent writer proposes that the whole civilized world shall contribute for a telescope which shall cost $1,000,000. Why should not America contribute enough from her vast resources to possess the most powerful one that can be built, and be the first among the nations to bring about great results, and make certainties of what seem now the shadowy possibilities of the future?

THE BATTLE OF LIFE AMONG PLANTS.

By MAXWELL T. MASTERS, M. D., F. R. S.

EVERY day, every hour, there is going on around us a veritable death-struggle. It excites little attention. People would be in no hurry to read the telegraphic dispatches concerning it from the seat of war, even if there were any to read. Special correspondents there are, but their letters are appreciated but by a few. Nevertheless, it cannot be said that mankind in general is not interested in the result of the struggle. On the contrary, little as the affair is heeded, it is of very serious import to the human race. Our food-supplies depend on it; the well-being of our flocks and herds is essentially dependent on it; the building of our houses, the fabrication of our raiment, are to a large extent contingent on it; nay, the soil beneath our feet, and the very sky above our heads, are materially, very materially, influenced by the result of the contest of which we are about to speak. Edward Forbes was wont to say that the movement of a periwinkle over a rock might be of greater consequence to the human race than the progress of an Alexander; and the results of the wars of the plants are assuredly of no less importance, seeing that the very existence of an Alexander depends in no slight degree upon them. The campaigns we speak of are real; they are not mental figments, or allegorical illustrations. Success in the practice of horticulture, of agriculture, of forestry, depends on the action we men take toward the combatants. If we remain neutral, the weakest goes to the wall, overpowered by the stronger; if we interfere, we exert a very powerful influence for the time; but, immediately we cease to exert our power, the combat begins again, and with enhanced violence. The essence of successful cultivation often consists almost entirely in the removal of the plant from the influence of that hostile "environment" to which, under natural circumstances, it would be subjected. It is this that accounts, in a great measure, though of course not wholly, for the oft-observed fact that certain plants, flowers, and fruits, attain far greater perfection in our gardens than they ever do in their native countries.

That a war of extermination is thus going on around us may strike some with surprise. They are so accustomed to associate flowers and plants with peace and repose, that they are astonished to find that other far less amiable ideas may, with even more justice, be associated with them. And yet a moment's reflection, or a passing glance at the nearest hedge-row or pasture, will show the reality of the struggle. All that beautiful disorder, that apparently careless admixture of divers forms and colors—the sweeping curves of the brambles, the entwining coils of the honeysuckle, the creeping interlacement of the ground-ivy or the pennywort—all are but indications of the fray that is constantly going on. It would seem as if the weakest must succumb, must be overpowered by the stronger-growing plants, and so they are at certain places and at certain times; but, under other conditions, the victory may be with the apparently weaker side, just as the slow-going tortoise may outrun the fleeter hare. In any case, the success is often only temporary; the victor becomes in time the vanquished; the vanquished, in its turn, regains its former conquest; and so on.

It is proposed in the following notes to give a few illustrations of the nature and effects of this conflict, of the way in which it is carried on, and of the circumstances which favor it.

Agriculturists had long been practically conversant with the advantages derivable from the practice of not growing the same crop on the same soil for too long a period. The advantages consequent on this so-called rotation of crops are due to more than one cause; but it was Dureau de la Malle who, in 1825, called attention to the phenomenon of natural rotation. From long observation of what takes place in woods and pasture-lands, he established the fact that an alternation of growth, as he called it, occurs as a natural phenomenon. In pasture-lands, for instance, the grasses get the upper hand at one time, the leguminous plants at another; so that, in the course of thirty years, the author whose observations we are citing was witness of five or six such alternations.

It follows from all this that a plant, as was pointed out by the late Dean Herbert, does not necessarily grow in the situation best adapted for it, but where it can best hold its own against its hostile neighbors, and best sustain itself against unfavorable conditions generally.

The sources of success in the contest are manifold; they vary more or less in each individual case. Probably they are never exactly the same; nevertheless, there are certain circumstances which must always be operative in conducing to the victory. A few illustrations must suffice. It is easy to understand why first-comers, duly installed, should have an advantage over later visitants; why the more prolific should outnumber the less fertile; and how it is that a perennial plant has a better chance on any given spot, *cœteris paribus*, than an annual, whose progeny would find the ground occupied, and their chances of survival materially interfered with by their longer-lived neighbors.

Again, there is no difficulty in understanding why such plants as quitch (*Triticum repens*) or bearbine (*Convolvulus sepium*) hold their own so tenaciously, and so much to the prejudice of their neighbors. The long, creeping, underground stems, rooting, or capable of rooting, at every joint, give them an immense advantage over plants not so favorably organized. The ends of the shoots of the convolvulus, moreover, dilate into tubers, which are thrust into the ground, to form in the succeeding spring fresh centres of vegetation. A great rooting-power is obviously of great benefit; not less so is an extensive leaf-surface. It is not only that the copious feeding-roots absorb the available nourishment from the soil, not only that the wide leaf-surface avails itself of every ray of sunlight, every whiff of air that plays over it, and thus serves to build up the tissues of the plant to which the root or leaf respectively belongs, but they practically oust other plants less favorably circumstanced than themselves. The roots occupy the soil, and rob the weaker plants of their share of its resources. The tree with dense foliage shuts off from its lowlier neighbor much of the light and air necessary for its existence; and hence, in a measure, the absence of vegetation in pine-forests or under the shadow of dense woods. Some plants there are specially organized to resist and overcome these hostile conditions. Among them are the climbers, the twining plants, and those with tendrils of one sort or another. The bramble or wild-rose, with its slender, arching, hook-beset branches; the wild-hop, with its coils of cord-like sprays; the clematis, clinging on firmly by means of its leaf-stalks to any thing it can lay hold of; the ivy, grappling with the trunk of a tree—all these are, in some sense, weakly plants; they would be overweighted in the struggle with their stronger neighbors, if it were not for the special adaptation of their structure just alluded to, and which enables them to bear their part bravely in the conflict.

It is easy to understand how an alteration of the conditions under which plants grow influences very materially the struggle we have been alluding to. A very slight change in climatal conditions—produced, for instance, by the growth of sheltering trees, or by the drainage of the soil—may be followed by the growth of quite a different set of plants from those that occupied the ground previously. The altered conditions have been advantageous to the one and disadvantageous to the other set of plants.

As an illustration of the complexity of the checks and relations between organic beings struggling together, Darwin mentions the case of a barren heath which fell under his observation, part of which was left intact, while another portion had been enclosed and planted with Scotch fir. The change in the native vegetation of the planted part of the heath was most remarkable. "Not only the proportional numbers of the heath-plants were wholly changed, but twelve species of plants, not counting grasses and carices, flourished in the plantations, which could not be found on the heath."

This sort of change was pointedly referred to by Dureau de la Malle, who relates how, after the felling of the timber in forests of a particular district of France, broom, foxglove, heaths, birch-trees, and aspens sprang up, replacing the oaks, the beech, and the ash, felled by the woodman. After thirty years, the birch and poplars were felled in their turn. Still very few of the original possessors of the soil, the oaks, etc., made their appearance: the ground was still occupied with young birch and poplar. It is not till after the third repetition of the coppicing—after an interval of ninety years—that the oaks and beech reconquer their original position. They retain it for a time, and then the struggle begins again.

Antiquarian researches also have proved that, in the natural state of things, without any violent change in external conditions, the nature of forests becomes altered. The Hercynian forests, of which Cæsar speaks, and which then consisted of deciduous-leaved trees, are now made up principally of conifers. A forest which, in the middle ages, was of beech, is now stocked with oak, and *vice versa*. Again, we have the evidence afforded by submerged forests and peat-bogs, according to which certain plants, now extinct in particular localities, once flourished there. We are not alluding to plants that may have required a different climate from what they now experience, but to such cases as the silver fir, the Scotch fir, *Pinus Mughus*, etc., which are found in this partially-fossilized condition in spots where there is apparently nothing to prevent them from growing now, where, in fact, they do grow well when planted.

Foresters in all countries are perfectly well aware of these facts, and botanists watch with interest the appearance of a different vegetation, when some accident has interfered with the previously-existing conditions. When woods are cut down, when soil from a depth is laid on the surface, when extensive fires occur, when lakes are drained; in fact, when any sudden alteration takes place in external circumstances, then we may expect to find a corresponding change in the vegetation. One set of plants profits by the change, another suffers. It may be asked, "Where do the new arrivals come from?" Sometimes, no doubt, the seeds are wafted from a distance, and, finding a suitable abiding-place, germinate. This is, perhaps, more especially the case with the spores of fungi, whose extreme minuteness favors their dispersion in this way. But it often happens that the facts of the case will not admit of such an interpretation, and then we can only fall back on the supposition that the seeds or bulbs existed in the soil, but under circumstances not favorable to their development.

The ground in this way is looked on by Alphonse de Candolle and Darwin as a vast magazine of seeds, etc., capable of retaining their vitality for a more or loss prolonged period, according to circumstances, and ready to avail themselves of any change that may be beneficial to them. That this is so in some places has been proved by results, but it seems equally clear that this does not hold good in all places. Allusion has already been made to the apparently capricious appearance of our British orchids. The downs or the fields that in one summer yielded abundance of bee, of fly, or of spider orchids, may, in another year, scarcely furnish a single one. The explanation of this peculiarity lies in the special organization of the plant, well described by Prillieux and other botanists, from whose observations it appears that the plants in question naturally pass through several stages, which, for our present purpose, it is not necessary to detail, and these stages may be prolonged according to circumstances. The flowering stage is thus arrived at in one season, while in another all the energies of the plant may be taken up in forming tubers and leaves. A very remarkable instance of the fact just alluded to was communicated to the writer by a competent observer, Mr. George Oxenden, of Broom Park, Kent. This gentleman had been acquainted with a particular field for some forty years, during which time it had been under the plough, but at the expiration of this period it was laid down in grass, when the very next year a profusion of bee-orchids was observed in it. In this case the time was too short for seeds to have germinated and to have progressed to the flowering state. There seems no other solution than that the tubers must have been in the ground some time previously, but that, from the ploughing and cropping of the soil, they had not had a fair chance of developing flowers.

The facts we have mentioned are, in the main, intelligible enough. We can see the why and the wherefore without much difficulty; but it is not so always. For instance, it is difficult to account for the signal defeat that native plants often incur at the hands of invading strangers.

Why does the water-cress, harmless enough in our ditches, block up the water-courses in New Zealand to such an extent as to become a costly nuisance? What can there be in English ditches and canals so propitious to the growth of the American water-weed (*Anacharis*) as to have caused it to obstruct even our navigable rivers? In America, whence it came, it is no more of an inconvenience than any other water-weed. Why in other places does the white clover (*Trifolium repens*) overcome the native grasses, and dispossess them of their territory? Why has a particular grass, the *Stipa tortilus*, invaded the South-Russian steppes to such an extent as to displace almost every other plant?

There are numberless such instances—from that afforded by the island of St. Helena, in which the original vegetation is almost completely dispossessed, and its room occupied by foreign importations, to the banks of a Surrey river, yellow with the flowers of an American balsam—and the reason is not obvious. The fact is patent, and is not without analogies in the virulence with which epidemic diseases spread when introduced for the first time among a population not heretofore subjected to them.

Such cases as these recall the opinions of Humboldt and others on the antipathies of plants. According to this notion, certain plants are positively injurious to others, not so much by any peculiarity of structural organization as by the excretion of matters hurtful to other plants. It has been asserted, for instance, that the darnel (*Lolium temulentum*) is injurious to wheat; that a species of thistle (*Serratula arvensis*) is obnoxious to oats; that a spurge (*Euphorbia Peplus*) and a scabious (*Knautia arvensis*) are detrimental to flax; and spurrey (*Spergula arvensis*) similarly prejudicial to buckwheat.

In so far as this detrimental influence is due to any excrementitious product from the plant, the verdict given by modern physiologists amounts to "not proven." Some would even say "not guilty;" but we do not see clearly how those who take this view can reconcile it entirely with the existence of that natural alteration of which Dureau de la Malle speaks, and which is admitted by all subsequent observers.

Mere exhaustion of the soil will not account for the phenomena in all cases, because a crop will fail on a particular soil after a while, and yet chemical analysis of that soil will reveal the fact that the particular elements required by a given plant are still contained in sufficient abundance in it. Land, for instance, that is "clover-sick"—on which, that is, good crops of clover cannot be grown—is by no means necessarily deficient in the constituent required for the growth of the plant; and, indeed, in the Rothamsted experiments the constituents in question have been supplied as manure, but without any good result.

Again, root-excretions (assuming their existence) cannot be productive of injury, as we are assured by Dr. Gilbert that clover has been grown in the same plot of garden-soil at Rothamsted for eighteen years in succession, while only a few hundred yards off no condition of manuring has hitherto been successful in restoring the clover-yielding capabilities of the land.[1] Reverting, however, to the alleged antipathies of one plant to another, we may make passing mention of the curious circumstance recorded by M. Paul Levi,[2] that the lianas or climbing plants of the forests of Central America have their likes and dislikes, and that they will not attach themselves to particular trees even when brought into juxtaposition with them. It is significent that the trees which are thus slighted by the twiners are just such as are ill-adapted for the support of such plants, being such as have tall, unbranched trunks, with smooth bark and a dense, overhanging, dome-like canopy of foliage. It is not only the climbing plants that refuse to grow on such trees, but to a less extent, also, the mosses, ferns, orchids, Bromeliads, and other epiphytal plants.

It is obvious, from what has been previously said, that human interference affects these internecine conflicts of plants very materially. It is clear also that the cultivator can very often avail himself of them to his own profit. From this point of view the experiments and observations carried on at Rothamsted by Mr. Lawes and Dr. Gilbert are most important, especially those relating to the struggle among pasture-plants, and the circumstances favoring certain plants more than their fellows. No detailed report of these particular experiments has hitherto been published, and only a few scattered notices in the Proceedings of the Horticultural Society (June 2, 1868) have appeared concerning them. We can, however, give some idea of their scope and nature by stating that a part of the park at Rothamsted, which has been under grass for centuries, has been divided into plots of equal size, placed side by side under conditions as nearly equal as possible. Some of these plots have been left unmanured; others, some twenty in number, have, for the last ten or twelve years, been subjected to various manures, the constitution and proportions of which are accurately determined. The general herbage of the park, like that of the unmanured plots, consists of some fifty species of plants, including sundry grasses, clovers, docks, umbellifers and other plants commonly found in such situations. In the several manured plots a change is observable, sometimes slight, at other times vast, and the change does not show itself so much in the superior luxuriance of any one plant, or in the starved condition of another, as it does in the more or less complete exclusion of certain plants, and in their replacement by others. Thus, while the unmanured plots contain, say, fifty species of plants, others comprise less than half that num-

[1] *Journal of the Horticultural Society.* New Series, vol. iii., p. 91.

[2] Cited in the *Gardener's Chronicle,* 1870, p. 383.

ber; from some plots the clovers and umbellifers are banished altogether, while in other cases they may be proportionately increased. Even among the grasses the competition is very severe, and the result in some cases is that all or nearly all have to give way to the cock's-foot grass (*Dactylis cæspitosa*), the growth of which is so fostered by certain manures as to cause it to overcome its fellows and remain master of the situation. To the plots to which a mixed mineral manure, consisting of salts of potash, soda, magnesia, and lime, is applied, but little difference in the number of species is observable. On the other hand, manures containing ammonia salts, or nitrates, cause a great diminution in the number of species living in the plot to which they are applied. While the unmanured plots furnish by weight about 60 per cent. of grasses, the remainder, consisting of plants of other families, the plots to which admixture of mineral and nitrogenous manures is added, contain as much as 95 per cent. of grasses, and these belonging to a comparatively very few species. Salts of potash and lime, which are comparatively inert as regards grasses, manifest their influence in increasing the vigor and the absolute numerical proportion of the leguminous plants.

The manner in which these results have been arrived at is worthy of a short description in this place.

Notes are taken at frequent intervals during the season of growth, the appearance of the plants noted, their relative luxuriance observed, and their comparative tendency to produce flower or stem and leaf, the abundance of flowers, etc., etc. Root-growth is studied, and also the character of the soil in the various plots, and the way in which its texture and its capacity for holding or transmitting water are modified according to the manure applied. When the crop is cut from each plot, its weight is estimated, and also the amount of dry produce. In some cases chemical analysis is pushed further, and the ashes duly examined. In addition to these no trifling observations, three "separations" have been carried out at regular intervals. These separations consist in the picking out, from a sample of a certain weight taken from each plot, every fragment of every species contained in the sample. In this way the relative quantity and weight of each of the different plants in the several samples are accurately determined, and the proportion in the whole plot computed. The labor is enormous; but the results, when fully brought out, must be most important, both as regards the scientific aspect of the question, the history of the life-struggle between plants so circumstanced, and also as regards the practical hints to be derived by the cultivator.

Some experiments of a somewhat similar character, and bearing directly on the struggle for life among plants, have been made by Prof. Hoffmann, of Giessen, and they are of such interest that we introduce here a very condensed account of them, taken from the pages of the *Gardener's Chronicle*, 1870, p. 664:

In a previous set of experiments the Giessen professor had ascertained that the particular plants under observation grew equally well in all the varieties of soil in which they were placed, provided due care was taken to prevent the growth of intruding weeds. Having arrived at this result, Prof. Hoffmann next left the several plants to themselves, with a view of ascertaining how they would comport themselves, without assistance, against the inroads of weeds. The result was, that the weeds completely gained the upper hand, as might have been expected from their known habit. The species which held out longest was *Asperula cynanchica.* This plant, after having been grown in a bed for three years, and protected from weed-invasion by the use of the hoe, was then left to take care of itself. It held out for four years, but was ultimately elbowed out by the intruders. Acting on the principle of "set a rogue to catch a rogue," Prof. Hoffmann then set himself to observe the results of the internecine struggle between the weeds themselves, thinking that the ultimate survivors would perhaps prove to have special affinities for the soil in which they grew.

Thus left to themselves, the beds became so densely covered, that, in a square foot, the professor counted 460 living plants, and the remnants of many others, which had succumbed in the encounter. Every year, in July, the plots were examined, and every year the number of species was found to have diminished. Melilots, at first abundant, gradually disappeared; *Artemisia vulgaris* succumbed after two or three years; and so on, till at length only a few species were left, and these not only persisted, but slowly gained ground from year to year, and ultimately remained in possession of the plot. The plots under observation were 2 mètres 30 cents. long, 1 mètre broad, and all as nearly as possible under the same conditions, save that the soil was varied, in some cases consisting of the ordinary soil of the garden, in others of an admixture of lime, in others of sand, or of sand and lime, and so forth.

Of the 107 species under observation, all, or nearly all, found the most essential requisites of their existence equally well in all the varieties of soil; so that, other conditions being equal, the nature of the soil was indifferent. The species which remained victors, all the others being ultimately dispossessed, were *Triticum repens* (couch), *Poa pratensis*, *Potentilla reptans*, *Acer Pseudo Platanus* (sycamore), *Cornus sanguinea*, native plants; and *Aster salignus*, *A. parviflorus*, *Euphorbia virgata*, and *Prunus Padus*, derived from other portions of the garden.

It may, therefore, be inferred that the district in which these experiments were made would, in process of time, if no obstacle were afforded, become covered with meadows and woods—meadows in the low ground and woods in elevated places. Again, the experiments show that the survival of certain plants has not been influenced by the nature of the soil; thus the couch-grass was ultimately spread over all the plots, whether of sand, or of loam, or of lime, whether drained or undrained. So also with *Poa pratensis* and *Potentilla reptans*. So that the chemical and physical nature of the soil, as has been so often shown in similar investigations, plays only a secondary part.

As to the action of shade, it was found by Prof. Hoffmann that low-growing plants, especially if annuals, disappeared rapidly, while taller-growing plants, such as couch, *Prunus Padus*, etc., survived. The survival of certain plants, then—couch, *Aster*, *Potentilla*, etc.—is due much less to external conditions than to the "habit" of the plant itself; that is to say, to the facility the plant has of adapting itself to varying external conditions, and thus of triumphing over others less favorably endowed in this wise.

The immediate source of victory lies in the powerful root-growth of the survivors, including under the general term "root" not only the root proper, but the offshoots and runners which are given off just below, or on the surface of the ground. Indeed, the latter habit of growth is more advantageous to plants in such a struggle than the development of the true root downward would be. Among those plants where the roots were equally developed there were, nevertheless, inequalities of growth, dependent, probably, on the greater need for light in some species than in others, etc.

It is clear from Prof. Hoffmann's experiments that, but for the continual use of the hoe, and the diligent extirpation of the weeds in our fields, the stronger-growing ones would not only destroy our crops, but also other weeds less vigorous than themselves. But they are not sufficient to explain all the conditions of this complicated problem; as is shown by the fact that, in the district adjoining the locality where Prof. Hoffmann's experiments were carried on, the predominant plants are not the same as those which ultimately proved victors in the experimental beds.

We may add that for two years a series of observations was carried on in the gardens of the Royal Horticultural Society, at Chiswick, with a view to ascertain how certain selected plants, twelve in number, and naturally growing in pastures, would be affected when growing by themselves, by the addition of manures of five different descriptions, and similar to those used at Rothamsted. In some cases the results of these experiments were unsatisfactory, from circumstances that need not be detailed here; still a large body of facts was accumulated, and, with reference to the property by which certain plants prove victorious in the struggle for life, it was clear that the natural habit or organization of the plant was, *cæteris paribus*, the mainspring of its success over its competitors. The several manures intensified or deteriorated this peculiar organization, as the case might be, and thus favored or impeded its growth accordingly.—*Popular Science Review.*

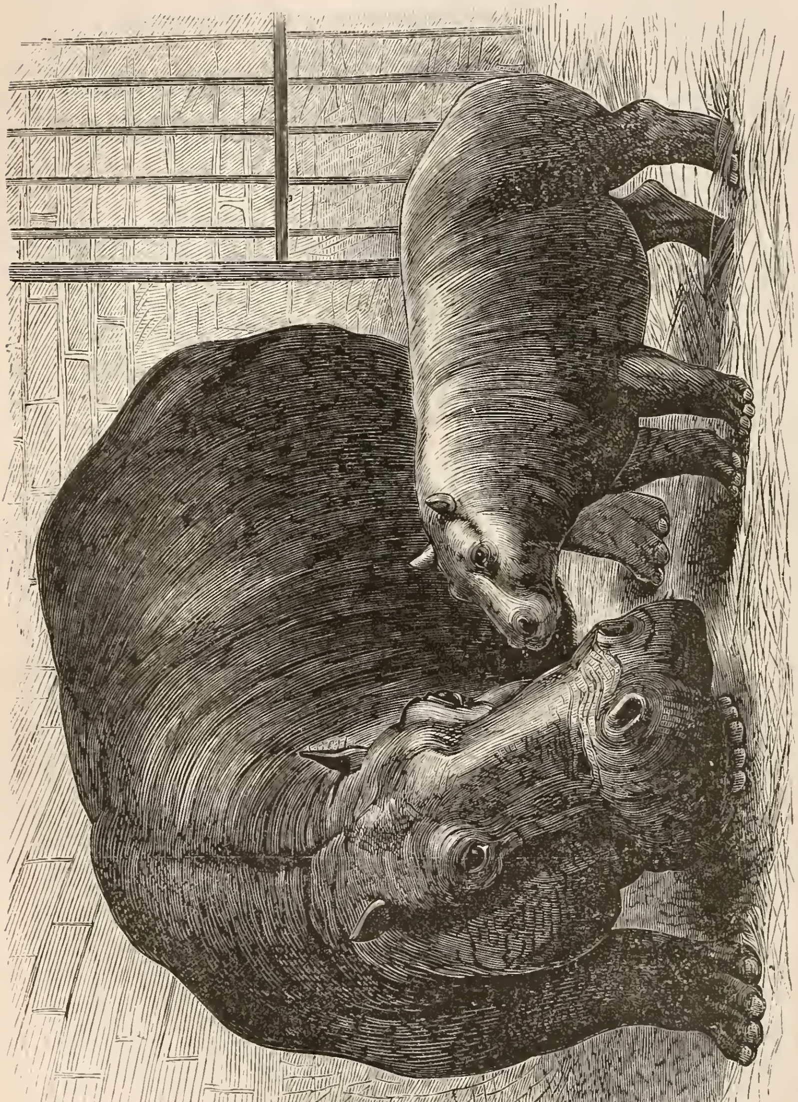
THE HIPPOPOTAMUS AND HER BABY.

By FRANK BUCKLAND.

ON the 5th of November, 1604, two hundred and sixty-eight years ago, the whole of London was in a state of commotion at hearing of the discovery of "Guy Fawkes" sitting in a cellar under the Houses of Parliament, on a powder-barrel, with a match in his hand, his intention being to blow up James I. and the House of Lords.

On the 5th of November, 1872, London was again put in a state of commotion by the appearance of another "Guy Fawkes;" this time, however, not in the cellar under the Houses of Parliament, but in the straw by the side of his mother in her den at the Zoological Gardens. In the engraving on page 86, you can now, kind reader, see the portrait of this celebrated animal, "Guy Fawkes," so called on account of the date of his birth. The father hippopotamus came over here in the year 1851, and was accompanied in his journey by the well-known captain of the "Rob Roy Canoe," who happened to be a fellow-passenger in the steamer with him. The female hippopotamus was sent over to England, by my friend Consul Petherick, at a later date. From these parents three young ones have been born at the Zoological Gardens; unfortunately, two of these interesting infants died. I made two casts of the first Baby Hippo: one cast is in the giraffe-house at the Zoological Gardens, the other is in my Fish Museum at South Kensington. The first two young ones remained by the head of the mother, evidently not knowing where the udder was. Mr. Bartlett, the talented and ever-obliging superintendent of the Zoological Gardens, tells me that, before these two hippopotami were born, the people at Paris and Amsterdam had written to him to advise him "never, on any account, to let the baby hippopotamus go into the water." He took their advice on the former occasions, but at the birth of "Guy Fawkes" he was determined to try the very reverse plan. He therefore allowed the young one to accompany its mother into the big bath. It is to Mr. Bartlett that must be ascribed the honor of the discovery *that the young hippopotamus certainly sucks under water.* It would seem, therefore, that the young hippopotamus has some peculiar anatomical structure which enables it to remain a much longer time under water than its parents.

A few days after the birth of the young one, Mr. Bartlett was watching it swimming about the tank. It then suddenly dived, but did not reappear for such a long time that he thought it had had a fit, and was lying drowned at the bottom of the tank. He therefore made arrangements to have the large plug pulled out—this plug had been fixed expressly for this purpose—and to run off the tank quickly, so as to resuscitate the little beast if possible. They were just going to do this, when Master "Guy Fawkes" suddenly reappeared, shaking his funny little horse-like ears, from the bottom of his tank, with a hippopotamic grin on his face, as much as to say, "Don't be frightened, I am all right; you don't know all about me yet!" The little beast had remained, without blowing or taking breath, actually under water for nearly twenty minutes. The parents have never been known to be under much over three minutes. I suspect Nature has given this



The Young Hippopotamus and its Mother.

wonderful power of remaining so long under water to the young hippopotamus, first of all, to enable it to suck—when the water has been clear, Mr. Bartlett has frequently seen it sucking under water—and, secondly, in order that it may be concealed from its enemies, though I am not at all certain but that a large crocodile would seize and swallow a young hippopotamus as a jack would swallow a roach.

Master Guy Fawkes, nevertheless, had one day a narrow escape of his life. In order to clean out the tank, one fine sunny morning the mother and child were let out into the pond outside. They both remained in the water as long as it suited them, and then the mother walked out with that peculiar stately gait which distinguishes this gigantic animal. The little one attempted to follow, but, unfortunately, he chose a landing-place at the corner nearest the giraffes' enclosure, just at the very point where there were no steps. The poor little fellow struggled and fought hard to get out, but could not, falling back exhausted into the water. His mother, seeing the distress of her child, immediately went back into the water, and, diving down, brought him up from the bottom. She then supported his head above water, in order to give him time to breathe. For nearly half an hour Mr. Bartlett and the keepers were in agonies. Of course, they dare not go to help Guy Fawkes, and there was no form of life-buoy they could throw to the struggling creature. At last the young one made a more vigorous effort than ever, when simultaneously the old one gave him a push with her tremendous head, and the little animal's life was thus saved. So we see that the hippopotamus is no fool; her instinct—mind, rather—told her how to save her young one.

It would be superfluous in me to attempt to describe this little animal, because every one ought to go and see it. It is about the size and shape of an ordinary bacon pig, but the color is something of a pinkish-slate. He knows his keeper very well: and when he has had his dinner is as playful as a kitten, popping and jumping about his den, and throwing up mouthfuls of hay, like a young calf. When first born he was small enough to come through the bars on to the straw outside his den, but soon he had grown so much that he could not get through. He used to put his head through the bars, and allow Prescott, the keeper, to rub his gums. The tusks of the lower-jaw were just beginning to cut the gum. His back teeth have not come yet; but they are obliged to be very careful about his diet, for he has already (when I write, in January) begun to pick a bit at the food prepared for him. I am pleased to be able to record that the council of the Zoological Society so fully appreciate Mr. Bartlett's cleverness in rearing this little beast, that they have voted him a silver medal and a purse, with a check in it. Prescott and the other keeper have also received a silver medal and a *douceur* from the society.

I now proceed to make some general remarks about hippopotami.

The hippopotamus is of some value commercially. The skin is made by the natives into whips, which, I believe, are used to beat delinquents in Egypt; and I am told that they are exceedingly formidable weapons. To make the whip, the skin is cut into triangular slips, about five or six feet long, one end being pointed, the other broad; it is then coiled upon itself, and afterward dried in the sun, and, when finished, is light, dry, and elastic. The teeth of the hippopotamus are also of commercial value. Their structure is very peculiar. I have a tooth now before; it is hollow at one end, like the tusk of an elephant. When the animal was alive, this hollow was filled with soft pulp. The tooth is always growing forward as the pulp solidifies behind. The reader can easily see how this is, by examining the front tooth of the lower jaw of the next boiled rabbit he has for dinner. The outside of the tooth of the hippo is formed of a glass-like, hard enamel; it is exceedingly dense, hard, and flint-like. I have just taken down my old regimental sword, and find that, by striking it at the proper angle, a shower of sparks fly away from the tooth, like the sparks from a boy's "fire-devil" made in form of a pyramid with wet gunpowder. The teeth of the hippopotami, as in the rabbit, are sometimes liable to deformity. In the College of Surgeons there is the tooth of a hippopotamus which has grown nearly into the form of a circle. These teeth are, I believe, much sought after by dentists for making artificial teeth; and when a piece can be had of such a form as that the teeth can be worked in enamel, they preserve their color almost as in the natural teeth. The price of hippopotami-teeth is about thirty shillings a pound. Artificial teeth are also made from the tusks of the walrus, the sword of the narwhal, and also the teeth of the cachelot whale.

Not long ago, the old male hippopotamus at the Gardens suffered much from a decayed tooth. In former times he would have been shot, as was poor "Chunee," the elephant at Exeter 'Change. Mr. Bartlett, superintendent of the Zoological Gardens, with his ever-ready talent in meeting all emergencies, determined to pull out the tooth. He ordered the blacksmith to make a pair of "tooth-forceps," and a tremendous pair they were. The "bite" of the forceps just fitted the tooth of the hippo. By skilful management, Bartlett managed to seize Master Hippo's tooth as he put his head through the bars. The hippo, roaring frightfully, pulled one way, Bartlett and the keepers pulled the other, and at last out came the tooth, and Hippo soon got well again.

No animal in this world is made without a purpose, and we always find that the structure of an animal is admirably adapted to its mode of life. I believe that one of the principal duties which the elephant and rhinoceros unconsciously perform, is to cut paths through the dense forests and jungles in which they live. The home of the hippopotamus is among the aquatic forests at the bottoms of large rivers, such as the Upper Nile. It is probable that, in the days of Moses, these animals abounded in Lower Egypt. I believe now they do not occur in any part of the Nile below the cataracts, the headquarters being the central and southern parts of Africa only; but I am afraid that, as civilization increases, so will the hippopotamus retreat. This huge animal spends most of its time in the water, and it comes out to feed at night. Above the cataracts of the Nile they are very destructive to the crops, as they eat an immense quantity, and trample down much more than they eat. The stomach contains as much as five or six bushels, and the large intestine is eight inches in diameter. They do not grind their food much, but rather munch it up. The reader should be curious to notice this at the Zoological Gardens. When the old hippo opens its mouth, a good-sized baby could as easily be put in as one puts a letter into a letter-box. As the elephant makes passes in the jungles, so it appears to me that one of the chief offices of the hippopotamus is to keep in check the dense vegetation in tropical climates, which, if allowed to accumulate, would block up the long reaches of rivers, and ultimately turn the flat lands into useless, fever-breeding swamps: so that we see this gigantic animal is of very considerable economic importance. This living machine for the destruction of fresh-water vegetation is admirably adapted for its work. Nature has not given him any hair, as that would be an incumbrance to it, and would not well conduce to its comfort when wallowing in the mud. The skin is, therefore, somewhat like that of a pig. If the animal had not some protection against the sudden changes of temperature induced by his going in and out of the water so frequently, he would always be either shivering or else unbearably hot. Nature, therefore, has given him a thick layer of fat between the skin and the muscles. The Dutchmen in Southern Africa call the hippopotamus the "Zee-coe," or "Sea-cow." My friend Mr. Mostyn Owen, who has travelled a great deal in Africa, tells me that they also call him the "Umzivooboo; and should the reader happen to visit the Dee, near Ruabon, he would be exceedingly likely to see a coracle floating down the river with a gentleman sitting in it fishing for salmon, and he would also probably observe the name "Umzivooboo" painted on the coracle in large letters.

In the water, the hippopotamus, though a gigantic beast, shows very little of his carcass. On referring to the engraving, it will be observed that the nostrils, eyes, and ears, are on the same level. The nostrils are each provided with a wonderful valve, by means of which he can open his nostrils to breathe, or shut them up to exclude the water. This beautiful mechanism is worked by what is called a "sphincter muscle." Reader, your own eyes are worked by a sphincter muscle. Stand opposite the looking-glass and wink at yourself, you will then see a sphincter muscle in operation. You do not require a sphincter muscle to your nose, because you are not amphibious. We find, however, that the seal, like the hippopotamus, can close his nose at will with a sphincter muscle. Go and look at the seal in the Zoological. The valve which works the blow-hole of the whale and porpoise is of an analogous character. Strange to say, we find an animal that is not amphibious has his nostrils protected by this curious and beautiful valve. But you will probably never guess what animal this is. Well, it is the camel—the "ship of the desert." In the desert, where the camel lives, there are often "sand-storms," and the Creator has provided the poor camel with this wonderful structure to save him from suffocation when these terrible sand-storms occur.

Shortly after the little hippopotamus was born in the Zoological, a young rhinoceros was born on board a ship in the Victoria Docks, and this poor little animal, whose value was very great, unfortunately died —his mother lay on him and crushed him with her great carcass. Never mind, better luck next time.—*Leisure Hour.*

EUTHANASIA.

THERE is a small knot of thinkers in Birmingham who come together to discuss philosophical topics, and call themselves The Speculative Club. In 1870 they published a volume of seven essays, which were written with much ability, and some of them with great boldness. The sixth article of this volume is by Samuel D. Williams, and is entitled "Euthanasia," which being interpreted means an easy or desirable mode of death. The writer begins by referring to the opposition which was made to the administration of chloroform for relief of pain, and more especially in cases of childbirth, which was regarded as a revolt against the divine decree, "In sorrow shalt thou bring forth." This prejudice having passed away, the writer raises the question of the application of chloroform to a relief of the sufferings which often attend the approach of death, and observes: "It is difficult to understand why chloroform should be rightly recurred to, to render less painful the natural painful passage into life; and yet, that it should be almost an offence to so much as suggest a like recurrence to it in the still more painful passage out of life." Why, he asks, should the patient about to be operated upon by the surgeon always have a refuge from suffering open to him, and yet the patient about to suffer at the hands of Nature the worst she has to inflict, be left without help or hope of help? Mr. Williams lays down and defends the following proposition: "*That in all cases of hopeless and painful illness it should be the recognized duty of the medical attendant, whenever so desired by the patient, to administer chloroform, or such other anæsthetic as may by-and-by supersede chloroform, so as to destroy consciousness at once, and put the sufferer at once to a quick and painless* *death; all needful precautions being adopted to prevent any possible abuse of such duty; and means being taken to establish, beyond the possibility of doubt or question, that the remedy was applied at the express wish of the patient.*"

After describing the tortures of lingering disease leading to inevitable death, the writer remarks:

"Cases such as this abound on every hand; and those who have had to witness suffering of this kind, and to stand helplessly by, longing to minister to the belóved one, yet unable to bring any real respite or relief, may well be impatient with the easy-going spirit that sees in all this misery—so long as it does not fall upon itself—nothing but 'the appointed lot of man;' and that opposes, as almost impious or profane, every attempt to deal with it effectually.

"Why, it must be asked again, should all this unnecessary suffering be endured? The patient desires to die; his life can no longer be of use to others, and has become an intolerable burden to himself; the patient's friends submit to the inevitable, but seek the means of robbing death of its bitterest sting—protracted bodily pain; the medical attendant is at the bedside with all the resources of his knowledge and his skill ready to his hand; he could, were he permitted, bring to his patient immediate and permanent relief. Why is he not allowed to do so, or, rather, why should not his doing so be a recognized and sovereign duty?"

To the objection that such a course would be a violation of the sacredness of life, the author rejoins:

"It may well be doubted if life have any sacredness about it, apart from the use to be made of it by its possessor. Nature certainly knows nothing of any such sacredness, for there is nothing of which she is so prodigal; and a man's life, in her eyes, is of no more value than a bird's. And, hitherto, man has shown as little sense of the value of man's life as Nature herself, whenever his passions or lusts or interests have been thwarted by his brother man, or have seemed likely to be forwarded by his brother man's destruction. A sense of the value of his own individual life to himself, man has, indeed, seldom been deficient in; and, by a kind of reflex action, this sense has slowly given birth to, and alway underlies, the sense, such as it is, of the value of other men's lives. But even to-day, and amid the most civilized countries of Europe, 'the sacredness of man's life' is thrown to the winds, the moment national or political passion grows hot, or even when mere material interests are seriously threatened. And, indeed, seeing that life is so transitory a thing, and that, at the best, it has to be laid aside forever, within the brief space of its threescore years and ten, it is hard to understand the meaning of the word 'sacred' when applied to it, except in so far as the word may signify the duty laid on each man of using his life nobly while he has it.

"The objection, then, based on the sacredness of life, may be dismissed; life is a thing for use, and is to be used freely and sacrificed freely, whenever good is to be won or evil avoided by such sacrifice or use; the man who is ever ready to face death for others' sakes, to save others from grinding pain, has always been reckoned a hero; and what is heroic if done for another, is surely permissible, at least, if done for one's self; the man who could voluntarily give up his life to save another from months of slow torture, would win everybody's good word: why should he be debarred from taking a like step when the person to be rescued is himself?"

It is furthermore urged that the sacredness of life is violated by existing medical practice, where, in cases of extreme and hopeless suffering, physicians administer drugs which give present relief, at the expense of shortening the patient's life.

To the objection that submission to the will of Providence forbids the shortening of pain in this way, the writer replies that "by the same principle we should submit to the will of Providence, and not seek to escape any pain. Not submission to surrounding circumstances—another term for God's will—but successful effort to bend them to his purposes, is man's chief business here; and every useful thing he does is a successful attempt to change, for his own or others' benefit, some of the conditions of life which surround him."

And thus the author of "Euthanasia" goes on attacking current ideas, and taking his own view of the economy of the world. Nature is to him not a mighty, beneficent mother, any more than she is a dread and relentless power—

"Red in tooth and claw
With ravine."

"Death by disease is always death by torture, and the wit of man has never devised torture more cruel than are some of Nature's methods of putting her victims to death.

"One of the main facts, then, that men have to make familiar to their thoughts and to adjust their lives to, is, that they are born into a world on the painful riddle of which speculation can throw no light, but the facts of which press hard against them on every hand; and from these facts the truth stands out clear and harsh, that not enjoyment, but, in the main, struggle and suffering, is what they have to look for, and that, to bring this suffering into bearable proportions, should be one of the chief aims of their lives."

The publication of this essay made but little stir at first. But it was separated from the volume, and published in a pamphlet with preface by Rose Mary Crawshay, and in this shape went to the third edition. The subject has been lately taken up in the *Fortnightly Review*, by Mr. Tollemache, under the title of "A New Cure for Incurables." Planting himself on Mr. Williams's ground, he reproduces his chief arguments, and adds others, with a view of strengthening the case. To illustrate how far pain reconciles us to death, he says:

"It is probably from surgical cases that the strongest arguments for euthanasia may be drawn. One of the highest authorities respecting such cases, the late Sir Benjamin Brodie, said that a very moderate amount of pain, if continued for a long time, would make any one heartily tired of life. He remarked also, that during his whole life he had known only two dying persons who showed any fear of death; and that both those died of bleeding. One cause of this singular circumstance probably was, that in these two cases there was hardly any pain to distract the mind; and the fact is curious, as showing how rare, in Sir Benjamin's experience, such painless deaths must have been."

The publication of this paper gave the discussion a fresh impulse, and numerous articles and letters have appeared in the English press, a few in favor of Euthanasia, but most of them decidedly against it. The *Saturday Review*, which had at first coquetted with Mr. Williams's theory as a novelty, upon sober reflection condemned it. The following is a part of its argument:

"It is of primary importance to inculcate a regard for the sanctity of human life. The reluctance to take life is indeed often pushed to an extreme by the opponents of capital punishments. But nobody can say that the mass of the population have as yet pushed their tenderness to the verge of effeminacy. A little story, related for a different purpose in the *Fortnightly Review*, illustrates very prettily a sentiment which is not so uncommon as might be desired. A sensible Scotchman watching by the bedside of his dying wife became impatient at the poor woman's anxiety to express her last wishes, and civilly requested her to 'get on wi' her deeing.' Now, among the poorer classes, where the inconvenience inflicted by people who 'take an unconscionable time in dying' is necessarily felt much more keenly than with people in a different rank, it is to be feared that this delicate hint is frequently followed up by some practical remonstrances. 'They pinched his nose beneath the clothes,' as Barham says, on the authority of a real occurrence, 'and the poor dear soul went off like a lamb.' Suppose, in fact, the case of a small cottage, where the invalid has become a heavy burden upon his family instead of a support, where the expense of providing medicine and attendance is most seriously felt, and where the sick-room is also the only dwelling-room, must there not frequently be a strong temptation to give him a quiet push or two along the downward path? If it were understood to be the law that invalids might be finished off when the case was hopeless, would not the temptation be frequently overpowering? Yes, it is replied, but the doctor and the parson must be present. That is all very well, but, if the practice became common, the people would quickly learn to take the law into their own hands. For it is to be observed that this is one of the cases where nobody could tell tales. A man on the verge of death does not require to have his throat cut or a dose of arsenic administered. A judicious shake, an omission to cover him properly, or the exhibition of an over-dose of laudanum, will do the business effectually, and no possible proof remains. Once allow that such things may be done with due precautions, and the precautions will soon be neglected as troublesome formalities. Why bother the doctor and the parson, why ask the sick man's consent, when the case is so clear? Of course the system need not be openly mentioned, but it would be speedily understood to be a highly convenient practice. The advocates of the scheme admit that the precautions of which we have spoken are absolutely necessary to prevent abuse; and we may add that it is simply impossible to enforce their observance. The practice itself once sanctioned, nothing is clearer than that people could, if they chose, carry it out in their own methods. No practice, again, could be more directly destructive of any strong persuasion of the sanctity of life. We need only read a few police reports, to understand how great is the existing tendency to violence of all kinds. Infanticide, as we know, prevails to a terrible extent, and wife-killing is not much less popular. Admit that the slaughter of invalids is also right under certain limitations, and it is easy to guess the consequences. The devotion which the poor display in cases of sickness is often among the most touching and amiable features of their character. In spite of the temptations we have noticed, they will often make noble sacrifices for the comfort of their dying relatives. Tell them plainly that they are rather fools for their pains than otherwise, and that they had better suggest suicide to the sufferer at the earliest opportunity, and you do your best to encourage, not merely suicide, but the cruel murder of a helpless man. A death-bed, instead of being the scene for calling forth the tenderest emotions and the noblest self-sacrifice, will be haunted by a horrid suspicion; the sick man fearing that his departure is earnestly desired, and his friends inclining to the opinion that killing is not murder, but kindness. The agitation of the question, what is the proper moment for smothering your dying father instead of soothing him, is not favorable to the development of those sentiments and the inculcation of those lessons which we generally associate with a sick-bed. In fact, the plan which certain eccentric philanthropists have advocated with such queer enthusiasm has a direct tendency to make men greater brutes than they are, and they are quite brutal enough already."

The *Spectator* objects that "the gravest of the merely rational objections we can bring against Mr. Tollemache is, that the ideas of which he is the advocate would plainly lead to two entirely new phases of feeling—impatience of hopeless suffering instead of tenderness toward it, where there was any legal difficulty in the way of getting rid of it by the proposed new law—and further, a disposition to regard people as 'selfish' who continued burdens upon others without any near and clear chance of the complete restoration of their own powers. Suppose it were permitted, as Mr. Tollemache wishes, that, on receiving the testimony of two or three physicians that a man's case is hopeless, he might, if he chose, elect to die, and that popular feeling came to sanction that choice as the right choice; what can be clearer than that, in the absence of any relations to whom such patients were dear, and who took pleasure therefore in prolonging their life, there would spring up a tone of habitual displeasure and irritation toward all who chose to go on giving unnecessary trouble to the world, and that very soon the standard of 'unnecessary' trouble would begin inevitably to become lower and lower, so that all the organized charity which now expresses itself in our hospital system would gradually suffer 'a sea-change' into something by no means 'rich or strange'—a sort of moral pressure, on poor invalids with any thing like a prospect of long-continued helplessness, to demand the right of ridding the world of themselves? We say that it is in this reflex effect of the new code of feeling upon our thoughts of disease, in the transformation it would certainly make of pure pity into impatience and something like reproachful displeasure, that the extreme danger of arguing out this sort of question, on the superficial considerations of the balance of pain and pleasure for each individual case, is best seen."

In a letter to the same paper, Mr. F. A. Channing says: "It is odd that men whose thought is mainly an outcome of modern science should fail to apply what is, perhaps, the most striking conception of modern science—that of time in relation to growth—to questions such as this of Euthanasia. If the central human instincts on which morality rests are the slowly-won product of ages of moral growth, a practice out of harmony with the most fundamental of those instincts, however speculatively excellent, could not be introduced without mischief. It would sacrifice too much of human feeling before it had time to put itself on a rational footing. Even in the individual philosopher it may be doubted whether reason could remodel instinct so as to make the sense of duty in such a case really complete. In most men the overridden instincts would merely be replaced by selfishness and cruelty to the helpless. They would lose the gentleness of strength, without gaining the least glimpse of the new morality.

"In Euthanasia we are offered a refined copy of the customs of some savage tribes, among whom life is more difficult to maintain, and so less valuable. But, then, their instincts are on the level of their customs. There is no jar between calculation and sentiment, such as we should have. Such a jar would make the practice, if adopted among us, spring from an estimate of personal advantages, and not from the half-thought-out sense of what is best, which is duty to most men. And, where such imperative instincts as the desire to keep life for ourselves and our friends at all costs are directly repressed in forming and acting on this estimate, the result must be moral loss to all except the philosopher who has had time to think his soul to oneness under the rule of reason. Euthanasia might become a wholesome doctrine if time should dissolve our present, perhaps animal, feelings, and replace them by more economical sentiments. But, as we are, it could only be an esoteric doctrine for the few who might have opportunities of ending hopeless misery by chloroform without giving needless pain to their friends. That is, it would be applicable only in the way Prof. Newman deprecates.

"It may, of course, be urged that there has been a latent change in men's notions of life and death which only needs expression, and that, if men talked freely, many would be found to talk Euthanasia. But facts like the growing aversion to capital punishment seem to point the other way. It is not because we feel less keenly the horror of murder, but because we are more scrupulous about taking even the least worthy life. Take the growing leniency toward infanticide. It is not because there is a change of opinion as to the duty of keeping even superfluous babies alive, but because we are more reluctant to take a woman's life in vengeance for a child's. Again, the sense that under certain circumstances it would be better for us or those dear to us to die, is surely far from being the true wish for death overwhelming the passionate impulse to keep up life to the last.

"It might be said, too, that the apology of Euthanasia stands on the same footing as the apology of cowardice, such as those French towns showed whose people did not think it worth while to hold out. Was it, or was it not worth while?" .

FREEZING OF PLANTS AND ANIMALS.

By Prof. FR. MOHR.

TRANSLATED FROM THE GERMAN, BY J. FITZGERALD, A. M.

IT is a fact, as yet unaccounted for, that, whereas the thawing-point of ice is constant, the freezing-point of water may, under certain conditions, be brought considerably below the temperature at which ice begins to melt. In glass vessels, with free access of air, pure water may be reduced to a temperature of from 15° to 17° Fahr. below the thawing-point, or, in a vacuum, from 18° to 20° Fahr. without freezing. A slight concussion, or contact with any rough surface, but especially with ice or snow, causes congelation at once, and the temperature ascends to the thawing-point. This rise of temperature is usually explained by the transition from the liquid to the solid form; but this is, after all, no true explanation, but merely a putting together of two facts which are apparently very nearly related.

The greater fall of the freezing-point *in vacuo*, as compared with its fall in the atmosphere, would appear to be ascribable to the absence of small corpuscles (spores ?). The melting of ice, as also the freezing of water, is a purely chemical process, though commonly called physical. Here heat is converted into a chemical effect; and, conversely, a chemical effect into heat. The phrase, "heat becomes latent," can no longer satisfy us, for latent heat is no heat at all. Here centre some facts belonging to the organic kingdom, to which my attention has been called by a letter received from Herr Fr. Dönhoff, of Orsoy.

The humors of butterfly-pupæ, which pass the winter in the open air, remain fluid in the coldest climate. If we cut in two such pupæ, at a temperature of 15° to 13° Fahr., the two halves quickly congeal and become as hard as stone. Juices of plants which do not freeze during winter, remain fluid, as is shown by the flexibility of the cabbage-leaf; while wet frozen linen may be broken, but refuses to bend. If you crush the leaves of green or red cabbage at a temperature below the freezing-point, they freeze at once; and, if you cut in pieces the ribs of a cabbage-leaf, you cannot press water out of the ends, for it freezes the moment they are cut up. Here the question arises how it is that watery fluids remain liquid in the tissues of animals and plants, whereas they at once freeze when the tissues are injured. A constant supply of heat is not to be thought of in pupæ or in eggs, such as is found in animals. Here I will bring forward two facts which throw some degree of light upon this question.

If you throw upon a glass plate a thin layer of flower of sulphur, and melt it by the application of heat, you will find that the larger particles are the first to become dry and solid on cooling, and to assume the yellow color. The smaller particles, on the other hand, remain fluid at common temperatures. Under the microscope they are transparent, and may be spread out with the dry finger; a fact which proves them to be viscous. Hence it follows that minute particles of sulphur may be cooled 170° below their melting-point without solidifying, but not so with larger particles.

Once, in preparing phosphuretted hydrogen, I suffered the mixture of phosphorus and caustic alkali to cool in the retort. On taking the apparatus apart on the next day, the phosphorus was found to be still molten at a common temperature, though its melting temperature is 115° Fahr. On repeating the experiment, it was found that the phosphorus might be cooled to 38° Fahr. before it solidified. Thus it remained fluid 77° below its melting-point.

Another observation was made, as follows: One night, at ten o'clock, with the temperature at 4° Fahr., a dense fog lay over the Moselle, through which, however, the brighter stars were visible. A cold current of air was coming from the direction of a neighboring hill, some 350 feet in height. The mist advanced steadily from the hill over the valley, but was constantly renewed, as the cold blast came in contact with the moist air over the stream. The following morning all the trees, especially the pines, were covered with a heavy hoar-frost, but on the land-side only, not on the water-side. On examining the ice-spicules, they were found to be perfectly crystalline, with angles of from 60° to 120°, and the long needles were made up of minute crystals set one upon another, and on one side resembling a flight of stairs. The particles of water floating in the air were, of course, of the temperature of the atmosphere, and consequently below the thawing-point. So soon as they came in contact with the points of the ice-spicules, they solidified, just as very cold water will when it is touched with ice. If the particles of mist had been changed into ice while still floating in air, they would have gathered upon the spicules of the pines in the shape of irregular pulverulent conglomerates, but would not have formed crystals. The plainly crystalline form of the ice-spicules shows, beyond a doubt, that the particles of mist were fluid at 4° Fahr. From these facts it follows that the minuter the particles of a liquid body are, the further they can be brought beneath their thawing-point without freezing.

If, now, we make an application of these facts to the above phenomena of organic Nature, we find that the reason why watery humors of pupæ, eggs, leaves and shoots, do not freeze, is because the cells containing these humors are very minute: in other words, the larger the cells the more quickly will plants freeze. It is well known that the young sprouts of vines, potatoes, and other plants, very readily freeze under a light frost, as was the case on May 12th of last year. Now, these young sprouts of vines are extremely juicy, containing a great quantity of water, and consequently but little cellulose. And, although the vines of the preceding year stood a winter temperature of 2° Fahr. without freezing, the sprouts of the self-same plants were frosted at 21° Fahr. Freezing expands the water and bursts the cells, and the break-up of the texture stops the process of growth. The buds of vines are more watery than the ligneous vines themselves. Hence, too, last winter, on the night of December 7th, many buds were frozen, while the vines were unhurt. On a vine eight feet in length, one of the latest of the buds rested on a wall covered with snow, and this shot forth in the spring, though all the other buds on the vine failed. It was the coming of the frost so early in December that made it so destructive, for the vines grow ever drier, and the sap tends toward the roots, from the beginning of autumn. This process had not gone so far in December as it would have gone in the first half of January, when usually the heavy frosts set in. Those branches whose buds are destroyed by frost, afterward die of their own accord, because the sap is unemployed, and the work of the leaf has ceased. Several of the vines remained green, and flourished toward the end of April on being pruned, but afterward dried up, as their buds were without life.

Hence we might draw the general conclusion, that all southern plants which are unable to endure our winter have large cells, and that, at the North, only such plants can be naturalized as answer to the requirement of small cells. As in Nature there are no *aims*, but only necessity, we may also hence conclude that a low temperature is favorable to the development of small cells. We have here, furthermore, an explanation of the hairy coats of animals. Animals which live in the North have all a thick coat, while those living in the south have a thin one. The mammoth was covered with hair 12 inches long, while his descendant, the elephant, who lives only in southern climates, is almost naked. Animals coming from the south, and acclimatized in the north, acquire hair, and *vice versa.* At the poles the fox wears his winter-coat the whole year through. In Sweden his coat remains for 10 months; in Germany, for 6 months; farther south, 3 months—until at last it is entirely dropped. No one will here discover an *aim*, but rather this necessary consequence, that a lower temperature produces a growth of hair in some way unknown to us. The same is true as to the development of cells. If, as a general rule, a warmer temperature necessitates larger cells, then the plants of southern regions will perish from the frost of northerly latitudes. The leaf of the potato-vine can never endure frost; but it is only in early spring that the plant can be visited by frost in temperate climates, and there is no frost in summer, while in autumn the tubers are protected by the soil. The young branches of the oak and beech (two trees belonging, indeed, to our climate) are quite as little able to endure the frost, and suffer from it severely during the night in spring. On the other hand, the spicules of the pine and the sword-shaped leaves of the yucca stand the severest cold of our winters.

As regards the temperature of those portions of plants (sprouts of vines, potatoes, etc.) which are killed by the spring frosts, we have no definite knowledge. It is probable that these parts become, by radiation, considerably colder than the shining bulb of the thermometer, and that they do not share in the temperature of the air, but fall to a lower temperature by radiation. In cloudy nights, when the thermometer shows 30° or 31° Fahr., nothing freezes, though the contrary takes place on bright nights. But here, too, the smallness of the cells appears to lower the freezing-point of water some few degrees.

Yet, in thus bringing into very probable relation two different facts, viz., the non-congelation of pupæ and leaves, and the fluidity of molten sulphur and of mist-particles, we have no complete explanation of the phenomenon. Such an explanation would show why it is that small particles have a different freezing-point from large ones of the same substance. This would require a very profound acquaintance with the nature of the molecular motion of heat, as also of chemical affinity.—*Gaea.*

PROFESSOR TYNDALL'S DEED OF TRUST.

I, JOHN TYNDALL, Professor of Natural Philosophy in the Royal Institution of Great Britain, having, at the solicitation of my friends, lectured in various cities of the United States, find the receipts and disbursements on account of these lectures to be as follows:

I. RECEIPTS.

From Boston, for six lectures	$1,500 00
" Philadelphia, for six lectures	3,000 00
" Baltimore, for three lectures	1,000 00
" Washington, for six lectures	2,000 00
" New York, for six lectures	8,500 00
" Brooklyn, for six lectures	6,100 00
" New Haven, for two lectures	1,000 00
Total receipts	$23,100 00

II. DISBURSEMENTS.

Before leaving England: wages of assistants during the preparation of the lectures; work of philosophical-instrument maker; new apparatus; sundry items for outfit; travelling expenses of myself and two assistants from London to New York—make a total of £671 6*s*. 8*d*. which, at the rate of $5.50 per pound, amounts to	3,692 31
In the United States: hotel and travelling expenses for myself and two assistants; other expenses incidental to lectures in Boston, Philadelphia,[1] Baltimore, Washington, New York, Brooklyn, and New Haven—covering a period of four months—*plus* travelling expenses of myself and my assistants from New York to London—make a total of	4,749 35
Present to Yale Scientific Club	250 00
Salaries to assistants for four months, £250, which, at $5.50 per pound, amounts to	1,375 00
Making the total disbursements	$10,066 66

III.

The total receipts are	$23,100 00
The total disbursements	10,066 66
Making the net proceeds of lectures	$13,033 34

As an evidence of my good-will toward the people of the United States, I desire to devote this sum of $13,033 to the advancement of theoretic science, and the promotion of original research, especially in the department of physics, in the United States.

To accomplish this object, I hereby appoint Prof. Joseph Henry,

[1] At Philadelphia I had no hotel expenses, but was most comfortably lodged at the house of my kinsman, General Hector Tyndale. He, I may add, paid his own hotel expenses wherever he accompanied me.

Secretary of the Smithsonian Institution, Washington City, D. C., Dr. E. L. Youmans of New York, and General Hector Tyndale, of Philadelphia, to act as a Board of Trustees to take charge of the above sum, to carefully invest it in permanent securities; and I further direct that the said Board shall, for the present, appropriate the interest of the fund in supporting, or in assisting to support, at such European universities as they may consider most desirable, two (2) American pupils who may evince decided talents in physics, and who may express a determination to devote their lives to this work. My desire would be that each pupil should spend four years at a German university, three of those years to be devoted to the acquisition of knowledge, and the fourth to original investigation.

If, however, in the progress of science in the United States, it should at any time appear to the said Board that the end herein proposed would be better subserved by granting aid to students, or for some special researches in this country, the Board is authorized to make appropriations from the income of the fund for such purposes.

I further direct that vacancies which may occur in said Board of Trustees, by death or otherwise, shall be filled by the President of the National Academy of Sciences.

If in the course of any year the whole amount of the interest which accrues from the fund be not expended in the manner before mentioned, the surplus may be added to the principal, or may be expended in addition to the annual interest of another year.

If at any time any organization shall be established, and money provided by other persons for the promotion of such original research as I have in view, I authorize the said Board of Trustees to exercise their discretion as to coöperating in such work from the income of this fund.

In witness whereof I have hereunto set my hand and seal this 7th of February, 1873, in the city of New York.

(Signed) John Tyndall (l. s.)

In presence of

(Signed) C. Burritt Waite,

(Signed) L. E. Fuller.

SKETCH OF SIR G. B. AIRY.

Sir George Biddell Airy, the Astronomer-Royal, was born on the 27th of June, 1801, at Alnwick, in Northumberland. His education was first cared for at two private academies, now at Hereford, now at Colchester. From the Colchester Grammar-School, when eighteen years of age, he went, in 1819, to Trinity College, Cambridge.

Three years afterward he was elected to a scholarship. In 1823, on his graduating B. A., young Airy came out as Senior Wrangler. In 1824 he obtained his Fellowship at Trinity. His degree of M. A. was taken in 1826, and he was simultaneously elected, though only then in his twenty-fifth year, as Lucasian Professor at Cambridge. Illustrious philosophers like Barrow and Newton had preceded him in the occupation of that historic chair. Latterly, however, the office had become, in a great measure, purely honorary, and might almost be said to have degenerated into a sinecure.

Prof. Airy, once elevated to that position, determined to avail himself of his professorship to the advantage alike of himself and the university. Consequent upon this determination, he for nearly ten years together—namely, from 1827 to 1836—delivered, with admirable effect, a series of public lectures on experimental philosophy, by which his scientific reputation was very considerably advanced. The series was all the more remarkable, inasmuch as it was one of the earliest means of effectively illustrating the marvellous phenomena constituting the now almost universally adopted undulatory theory of light. Two years after Prof. Airy's induction into the chair established by Lucas, the estimation in which he was held at the university was still further signalized by his election to the Plumian Professorship. Nominated to that post of authority and honor, he at once obtained, by right of his position, the supreme command of the Cambridge Observatory.

Already, even then, he began those remarkable improvements in the method of calculating and publishing the observations which eventually became the law at Greenwich and at all the other great observatories. As indicative of the energy and daring of his innovations at Cambridge, he superintended the construction and mounting, one after another, of a series of renowned astronomical instruments. In that observatory, he brought into use a noble specimen of the equatorial, being that peculiar description of telescope which has its fixed axis so directed to the pole of the heavens that the tube may be readily made to follow any star by a single motion. There, moreover, he brought into effective employment a mural circle of admirable construction, bearing a telescope which revolves in the plane of the meridian, the whole being rigidly bound into some immovable structure of ponderous masonry. Prof. Airy, in his thirty-fourth year, became Astronomer Royal. Thirty-eight years have since elapsed. Under his directions, it is hardly too much to say that the organization of the establishment at Greenwich has been completely transformed. He has given great regularity to its minute and multiform proceedings. He has contrived to establish newer and sounder methods of calculation and publication. He has introduced, constructed, mounted, and employed, a series of novel instruments for the advancement of astronomic research. Perhaps the finest transit-circle at present anywhere to be found is the one he there constructed in 1860, the circles being no less than six feet in diameter, and the telescope affixed between the two graduated disks being twelve feet long, and having an object-glass of as many as eight inches in aperture. Through this splendid apparatus the altitude of the stars, as well as the time of meridian passage, is now unerringly marked at the great national observatory. But the greatest of all the instruments established by him at Greenwich is a large, first-class equatorium, well known among astronomers.

During Sir George Airy's rule at the observatory he has, in the midst of his other labors, reduced the Greenwich observations of the moon and of the planets from 1750 down to the present time. Incidentally he has thrown considerable light on ancient chronology by his ingenious calculation of some of the most renowned of historical eclipses. Thrice the Astronomer Royal has taken occasion to visit the European Continent for the purpose of making more accurate observations upon the solar eclipse then eagerly anticipated. In 1854 he approximated more nearly than any previous investigation had done to the weight of the earth, through a series of experiments on the relative vibration of a pendulum at the top and bottom of Harton Coal-pit.

Sir George Airy has been repeatedly called into council on matters of grave difficulty by the government. He was chairman of the royal commission empowered to supervise the delicate process of contriving new standards of length and of weight, the old standards having been destroyed in 1834 in the conflagration of the Houses of Parliament. He was consulted some years afterward by the government in respect to the bewildering disturbance of the magnetic compass in iron-built ships-of-war. Thereupon he contrived an ingenious system of mechanical construction, through a combination of magnets and iron. The result was successful, and the system generally adopted. He conducted the astronomical observations necessary to the drawing of the boundary-line now traceable on the map of the New World between the Canadas and the United States. During the battle of the gauges in the railway world Sir George Airy strenuously advocated the narrow gauge, and he just as energetically advocates the adoption of a decimal currency. The writings of the Astronomer Royal are numerous. He has contributed largely to the Cambridge Transactions and the Philosophical Transactions. His pen has notably illustrated the memoirs of the Astronomical Society. He has written abundantly for the *Philosophical Magazine*, and still more abundantly, under his reversed initials, A. B. G., in the columns of the *Athenæum*. His principal works, however, are those which may be here rapidly enumerated: "Gravitation," published in 1837, was written originally for the "Penny Cyclopædia." "Mathematical Tracts" have reached a fourth edition, as have also his "Ipswich Lectures on Astronomy." In 1861 appeared his treatise on "Errors of Observation;" in 1869 his treatise on

"Sound;" and in 1870 his treatise on "Magnetism." Sir George Airy's well-known work on "Trigonometry" was published in 1855. Another work of his, entitled "Figure of the Earth," has yet to be named, as well as the luminous paper on "Tides and Waves," contributed by him, first of all, to the "Encyclopædia Metropolitana." Even while simply Professor of Astronomy at Cambridge his "Astronomical Observations," issuing from the press between 1829 and 1838, extended to nine quarto volumes, and were adopted at once as models for that class of publication.

Sir George Airy has received the Lalande Gold Medal of the French Institute in honor of his important discoveries in astronomy. For his successful optical theories he has had awarded to him the Copley Gold Medal of the Royal Society. The Royal Gold Medal of the same society has been given to him in recompense for his tidal investigations. Twice the Gold Medal of the Royal Astronomical Society has been his—first, for his discovery of an inequality of long period in the movements of Venus and the earth; secondly, in return for his reduction of the planetary observations. He has been enrolled among the most honored members of the Royal Astronomical Society, of the Cambridge Philosophical Society, and of the Institute of Civil Engineers. For many years past he has been among the foreign correspondents of the Institute of France, as well as of several other scientific academies on the Continent. He has received honorary degrees of D. C. L. and LL. D. from each of the three great universities—Oxford, Cambridge, and Edinburgh. On May 17, 1872, Sir George was gazetted a Knight of the Bath. His claim upon the remembrance of posterity, however, will be that of having occupied with distinguished ability the post of Astronomer Royal of Great Britain during considerably more than the lifetime of a whole generation.

The *Illustrated Review*, a London biographical and literary periodical, to which we are indebted for the preceding statements, remarks that, since the death of Sir John Herschel, on the 11th of May, 1871, Sir George Airy, the Astronomer Royal, is the admitted master of the sublime science. There are other eminent English astronomers—as John Hinde, the discoverer of many asteroids, and John Adams, also a Cambridge Senior Wrangler and the rival of Urban Leverrier, who groped his way by mathematical calculation to the discovery of the position of the hitherto unknown planet Neptune. If incidents as brilliant and remarkable as these are wanting in the history of Sir George Airy, his claims to respect are equally valuable, solid, and enduring.

CORRESPONDENCE.

THE SPHERE AND LIMITS OF SCIENCE.

To the Editor of the Popular Science Monthly:

As you have done my brief after-dinner speech (a kind of performance that usually perishes with the occasion) the honor of an elaborate criticism, which I think a little one-sided and unfair, I ask the privilege to reply.

You say that I used the occasion of the Tyndall banquet "to give a lesson to the scientific gentlemen present as to the proper limit of their inquiries." But that is hardly a just representation. Neither in matter nor manner did I pretend "to instruct" anybody; but, assuming that the Press, on which I was invited to speak, was a kind of universal reporter, I simply asked a few questions of an audience so competent to give the answer, as to the validity of certain speculative opinions confidently put forth in the name of science. That the mode of doing so was neither presumptuous nor offensive, I infer from the cordial approval given to my remarks by eminent scientific gentlemen, both at the time and since.

You seem to resent the speech as an impertinence in saying that "it has ever been a favorite occupation of outsiders to instruct the investigators of Nature where they must stop," etc. But does Science set up any pretension to the character of an exclusive church? It is true I am an outsider; i. e., I have made no discoveries in science; I have cultivated no special branch of it as a pursuit; all that I know of it I have learned from others, by diligent though somewhat desultory reading, for thirty years past; but may I not, therefore, have an opinion of what I am taught? Is it temerity to endeavor to distinguish what is real science from what is not, particularly at a time when there is so much put forth that is likely to confuse the careless mind?

Be that as it may, what I complain of is, that you class me among the bigots, who in every age have protested against the progress of knowledge, alleging that I presented myself as "the champion of imperilled faith," whereas my protest was merely in behalf of true science against false. And, in order to make out your case, you suppress all reference to the first part of my speech, in which I uttered, as fully as the occasion allowed, the highest estimations of Science and my almost unbounded hopes of its future. Permit me to revive what I said: After hailing Science as the "King of the Epoch," to which all other forms of intellectual activity were doing homage, and as the "mighty Magician," that by its brilliant and fertile researches surpassed whatever the imagination had depicted in fable, I continued: "Science is to me not only a proof of man's intellectual superiority, and the seal of his emancipation from the tyranny of ignorance, but the pledge of an unimaginable progress in the future. By the beautiful uniformities of law, which it discovers in Nature, it discharges the human mind of those early superstitions which saw a despot god in every bush, whose wanton will paralyzed the free flight of our intellect, and debauched our best affections. Neither the tempests nor frowns of Nature are terrible to us, now that we may bend her most hostile forces into willing obedience, and find her full, not of malice, but of good-will. For, out of that benignity, and our supremacy over it, will yet come a power that will enable us to transform these poverty-smitten, sordid, unjust, and criminal civilizations, into happy and harmonious societies, when every man shall be glad in the gladness of his fellows, and, for the first time, feel the assurance of a universal Divine paternity. Science, moreover, in wresting from Creation her final secrets, will furnish to the philosophic mind the means of a more effulgent and glorious solution of the dark problems of life and destiny than it is possible to reach by unaided conjecture. She will prove what the spiritual insight of the seers has only dimly discerned, that Nature, which now seems so inscrutable to us, so hard and unfeeling toward human hopes and desires, is the most kindly and generous of helpmates, and not a tyrannic lord; that these outward appearances are but the shows of an inward reality which is entirely human; that these phenomenal forms and events are but the symbols of an eternal Love and Truth, which the great spiritual Sun of the Universe projects and photographs upon the sensitive plates of our finite human intelligence."

Thus, while I ascribed to science a potent and beneficent efficacy, first, in discharging the mind of its fears of Nature and of other superstitions; second, in perfecting civilization; and, lastly, in promising the surest groundwork for speculative generalizations, both naturalistic and theological, you represent me as deprecating its influences, and as even questioning its utility. That was scarcely fair. How, indeed, could I do so? Holding profoundly to the conviction (how derived is not here the question) that there is but one real Life in the Universe, whose infinite Love is the ground of all Force, and whose infinite truth is the ground of all Law, and that phenomenal Nature is but the varied manifestation of that life to and through the human mind, it would be intellectual suicide in me to attempt imposing fetters upon any legitimate search of Nature's methods. Every step we make in unfolding her secrets is a new revelation of an adorable goodness and wisdom, and a new help toward a nobler future.

But then I said—and it was the whole purport of my speech, made in the interests of science as well as religion—that we can only expect these results from true science, which investigates what Nature really *is*, and not from a hasty and presumptuous science, which pretends to give us what Nature *may be supposed to be*. And my criterion of true science, suggested in a phrase, was, that the methods and results of it bear the impress of exactitude or certainty. You remark, as if you did not receive these simple and fundamental principles, that the "exact sciences" are exact, while others are not. There, I think, we differ or misunderstand each other. I am aware that none of the sciences are exact in the mathematical sense of the word, save the ideal or abstract sciences; but it is none the less true that the real or concrete sciences are exact, in the usual sense of the word, both in their methods and products. If they are not exact, where does the inexactness come in? In the observation of facts? Then the induction is vitiated. In the induction itself? Then the law arrived at is imperfect. In the deductive verification or proof? Then we have no reason for trusting our process. Biology, psychology, and sociology, you say, are sciences and certain sciences; to which my reply is, that, to the extent in which they are not precise, they are not sciences. Indeed, saving in a popular and convenient sense, I should be disposed to doubt whether they are yet to be ranked as more than inchoate sciences. They belong to the domain of science, have gathered some of the richest materials for science, and have attained to some extent a scientific value; but there is yet so much uncertainty hanging over broad regions in each that we must await the future for the resolution of many unresolved questions, which may give a new aspect to the whole. Biology is the most advanced, but rather in its natural history and classification, than in its knowledge of the profounder laws of life, that are yet to be found. Psychology is so little of a science, that the teachers of it hardly agree on the fundamental points; or, if it be a science, whose exposition of it are we to accept, Sir William Hamilton's or Mr. Mill's, Herbert Spencer's or Dr. Porter's, who all profess to be experimental and inductive, and all disagree? As to Sociology, the name for which was invented only a few years since by Comte, it is still in a chaotic condition; and, unless Mr. Spencer, whose few introductory chapters are alone made public, succeeds in giving it consistency and form, it can hardly be called more than a hope. But, be the truth what it may, in respect to these particular branches of knowledge, I still insist that certainty is the criterion of true science, and that, if we give that criterion up, science loses its authority, its prestige, its assurance of march, and its sovereign position as an arbiter in the varying struggles of doctrine.

Well, then the examples I gave, without mentioning names, of what I considered false science, were, first, the gross materialism of Büchner, who derives all the phenomena of life from simple combinations of matter and force; second, the atheism of Comte, whose scientific pretensions Mr. Huxley ridicules, and whose results Mr. Spencer impugns; third, the identification of mind and motion by Mr. Taine, which Tyndall, in one of his most eloquent passages, says explains nothing, and is, moreover, utterly "unthinkable;" and, fourthly, Mr. Spencer's evolutionism, which, in spite of the marvellous ingenuity and information with which it is wrought out, seems to me, after no little study, as it does to others more capable than I am of forming a judgment, after greater study, to be full of unsupported assumptions, logical inconsistencies, and explanations that explain nothing, while in its general character it tends to the sheerest naturalism. Now, was I right or wrong in regarding these systems as speculative merely, and not scientific? Am I to infer, from your objections to my remarks, that The Popular Science Monthly holds materialism, atheism, and naturalism to be the legitimate outcome of science? Else why am I arraigned for designating them as unworthy of science, and as having no rightful claims to the name, under which their deplorable conclusions are commended to the public?

My object in these allusions was to indicate two capital distinctions, which it is always important to keep in view when estimating the scientific validity of a doctrine. The first is, that many questions determinable by science are not yet determined by it; and, until they are so determined, are to be regarded only as conjectural opinions, more or less pertinent or impertinent. Of this sort I hold the Nebular, the Darwinian, and the Spencerian views to be, i. e., hypotheses entirely within the domain of scientific theory, and capable, to a certain extent, of explaining the phenomena to which they refer; highly plausible and probable even at the first glance; but disputed by good authority, and not at all so verified as to be admissible into the rank of accredited science. They are suppositions to which the mind resorts to help it in the reduction of certain appearances of Nature to a general law; and, as such, they may be simple, ingenious, and even beautiful; but thus far they are no more than suppositions not proved, and therefore not entitled to the authority of scientific truth. You are probably too familiar with the history of scientific effort—which, like the history of many other kinds of intellectual effort, is a history of human error—not to know that, while hypothesis is an indispensable part of good method, it is also the part most liable to error. The records of astronomical, of geological, of physical, of chemical, and of biological research, are strewn with the *débris* of abandoned systems, all of which once had their vogue, but none of which now survive and many of which are hardly remembered. Recall for a moment the Ptolemaic cycles and epicycles; recall Kepler's nineteen different hypotheses, invented and discarded, before he found the true orbital motion of Mars; recall in geology Werner and Hutton, and the Plutonians and the Neptunians, superseded by the uniformitarians and the catastrophists, and now giving place to the evolutionists; recall in physics the many imponderable fluids, including Lamark's resonant fluid, that were held to be as real as the rocks only a few years ago; recall in chemistry, not to mention the alchemists and phlogistion, a dozen different modes of accounting for molecular action; recall in biology the animists and the vitalists, the devotees of plastic forces, of archei, of organizing ideas, and of central monads, all of them now deemed purely gratuitous assumptions that explained nothing, though put forth as science.

Even in regard to the question, so much discussed at present, of the gradual progression and harmony of being, the old monadology of Leibnitz, which endowed the ultimate units with varying doses of passion, consciousness, and spontaneity, and which built up the more complex structures and functions of organisms, from the combination of these—this theory, I say, somewhat modified and stripped of its mere metaphysical phases, could be made quite as rational and satisfactory as the more modern doctrines of development. Indeed, some eminent French *philosophs*—Renouvier, a first-class thinker, among the rest—have gone back to this notion; Darwin's suggestion of pangenesis, and Mr. Spencer's physiological units, look toward it; and its adherents maintain that, beset with difficulties as it is, though not more so than others, it has yet this merit, that it leaves a way open to speculative thought, alike removed from the vagaries of mere ontological abstraction and the entire subjection of mind to a muddy and brute extraction. They might add, also, that this theory shows that, in the interpretation of the serial progress of being, we are not altogether shut up to a choice between specific and spasmodic creations and his own theory of evolution, as Mr. Spencer triumphantly assumes throughout his argument. Indeed, nothing is more easy than to make theories; but the difficulty is to get them adopted into Nature as the satisfactory reason of her processes. But, until they are so adopted, they are no more than the scaffolding of science—by no means the completed structure. Now, have the Darwinian and the Spencerian hypotheses been so adopted? Can we say that any questions on which such cautious observers and life-long students as Darwin, Owen, Huxley, Wallace, and Agassiz, still debate, are settled questions? Prof. Tyndall, for example, says: "Darwin draws heavily upon the scientific tolerance of the age;" and again, that "those who hold the doctrine of evolution are by no means ignorant of the uncertainty of their data, and they yield no more to it than a provisional assent." With what propriety, then, can a merely provisional conclusion be erected into an assured stand-point whence to assail traditionary beliefs as if they were old wives' fables?

More than that, a theory may be far more advanced than any of those; may be able to account satisfactorily for all the phenomena within its reach, as the Ptolemaic theory of the sidereal appearances did, even to the prediction of eclipses, or as the emanation theory of light did, up to the time of Dr. Young, and yet turn out altogether baseless. Nature is a prodigious quantity and a prodigious force; with all her outward uniformities she is often more cunning than the Sphinx; and, like Emerson's Brahma, she may declare to her students—

> "They know not well the subtle ways
> I keep, and pass and turn again."

We have looked into her face a little, measured some of her ellipses and angles, weighed her gases and dusts, and unveiled certain forces, far and near—all which are glorious things to have done, and some of them seemingly miraculous; but we are still only in her outer courts. Humboldt's "Cosmos," written thirty years ago, is said to be already an antiquated book; and Comte, who died but lately, and whom these eyes of mine have seen, could hardly pass a college examination in the sciences he was supposed to have classified forever. Let us not be too confident, then, that our little systems of natural law will not, like other systems of thought spoken of by Tennyson, "have their day."

The other distinction I had in mind, in my speech, was that, while there are some problems accessible to scientific methods, there are others that are not; and, that any proffered scientific solution of the latter, either negative or affirmative, is most likely an imposition. What I meant was that science, according to its own confession, that is, according to the teachings of its most accredited organs, pretends to no other function than to the ascertainment of the actual phenomena of Nature and their constant relations. The sphere of the finite and the relative, i. e., of existence, not of essence, and of existence in its mutual and manifested dependencies in time and space, not in its absolute grounds, circumscribes and exhausts its jurisdiction. Was I wrongly taught, Mr. Editor? Does science assert for itself higher and broader pretensions? Does it propose to penetrate the supernatural or metaphysical realms, if there be any such? Does it intend to apply its instruments to the measurement of the infinite, and its crucibles to the decomposition of the absolute?

You, as a man of excellent sense, will promptly answer, No! But, then, I ask, is thought, whose expatiations are so restless and irrepressible, to be forever shut up to the phenomenal and relative? Is it to be forever stifled under a bushel-measure, or tied by the legs with a surveyor's chain? May it not make excursions into the field of the Probable, and solace itself with moral assurances when physical certainties fail? May it not, mounting the winged horse of analogy, when the good old drudge-horse induction gives out, fly through tracts of space and time, not yet laid down on the map? May not some men have insights into the working of laws yet unexplored, such as Mozart had into the laws of music, and Shakespeare into the laws of the human heart? Assuredly you cannot say nay, in the name of science, which, as we agree, being confined to the phenomenal and relative, has no right to pronounce either one way or the other, as to what, by supposition, lies beyond the phenomenal and relative. That supposed beyond may be wholly chimerical; but it is not from science that we shall learn the fact, if it be a fact. In other words, I contend—and here I hit upon the prime fallacy of many *soi-disant* scientists—that science has no right to erect *what it does contain into a negation of every thing which it does not contain.* Still less has it a right to decide questions out of its confessed province, because it cannot reach them by its peculiar methods, or subject them to its peculiar tests?

Fortunately for me, though you take me especially to task for it, I am sustained in this position by some of the most eminent men of science of the day, and I may say, by great numbers of them, as I have reason to know. You yourself published, only a little while since, Dr. Carpenter's address, as President, to the British Association for the Advancement of Science, in which, after expounding very clearly man's rightful function as "the interpreter of Nature," he said: "The science of modern times, however, has taken a more special direction. Fixing its attention exclusively on the order of Nature, it has separated itself wholly from theology, whose function it is to seek after its cause. . . . . But, when science, passing beyond its own limits, assumes to take the place of theology and sets up its own conception of the order of Nature as a sufficient account of its cause, it is invading a province of thought to which it has no claim, and not unreasonably provokes the hostility of those who ought to be its best friends."

In the same number you published Dr. Gray's address, as President of the American Association, wherein, after quoting Miss Cobbe's remark, that "it is a singular fact, that when we find out how any thing is done, our first conclusion is, that God did not do it," he adds, that such a conclusion is "premature, unworthy, and deplorable," and concludes with the hope "that, in the future, even more than in the past, faith in an order which is the basis of science will not (as it cannot be reasonably) be dissevered from faith in an ordainer which is the basis of religion." And, my old friend, and honored teacher, Dr. Henry, from whose enthusiasm for natural studies I imbibed whatever taste for them I have retained, in a letter addressed to this Tyndall banquet, and published in your last number, wrote: "While we have endeavored to show that abstract science is entitled to high appreciation and liberal support, we do not claim for it the power of solving questions belonging to other realms of thought. . . . Much harm has been done by the antagonism which has sometimes arisen between the expounders of science on the one hand, and those of theology on the other, and we would deprecate the tendency which exhibits itself in certain minds to foster feelings antagonistic to the researches into the phenomena of Nature, for fear they should disprove the interpretations of Holy Writ made long before the revelations of physical science, which might serve for a better exegesis of what has been revealed; and also the tendency in other minds to transcend the known, and to pronounce dogmatically as to the possibility of modes of existence on which physical research has not thrown, and we think never can throw, positive light." Now, here is precisely, though not all, my meaning, and yet you rap me over the knuckles for it, while you publish the praises of Carpenter, Gray, and Henry.

All these illustrious men admit the limits of Science, and also the possibility of passing beyond them. As men of good common-sense, and no less as philosophers and scientists, they are perfectly aware that, while the scope of Science lies within the contents of experience, and of the inductions drawn from that experience, it is hazarding the character of it to go further. They feel too, no doubt, what I certainly do, that there are certain broad, deep, ineradicable instincts of the human mind, which, however they originated, whether implanted there by creative act, or formed by the slow growth of thousands of years, are now become the inexpugnable basis of all human credence and all human action. The convictions of the reality of Nature, of the independence of Mind, and of the being and authorship of God, in spite of every effort of Philosophy to get rid of them, either by declaring them unthinkable, or by merging one in the other, always return as the final no less than the initial postulates of thought. Any scheme of the universe, therefore, which leaves any of them out, declares itself impotent, like the project of an edifice which makes no provision for the corner-stones. Innumerable such schemes have gone before, and floated as bubbles for a while, but the first touch of these Realities broke them into thin air.

What the relations of these grand primal factors of the problem of existence are, or how they are to be harmonized with each other, we do not know; perhaps we never shall know; but, I think we shall learn more and more of them, and, in due time, by the instrumentalities that are given us. We shall learn of Nature, and of Man, so far as he is a dependant and denizen of Nature, by that digesting of experience which is the peculiar work of science. We shall learn of Man, so far as he has a deeper spring of life than observation reaches, from its wellings-up into consciousness at those rare moments of insight which often seem so mysterious; and we shall learn of God through both; i. e., as he works with the stupendous forces of time and space, which symbolize him, and as he inspires our feeble loves and wisdoms, which are no less symbols of him, with an intenser sense of his own supernal love and wisdom.

But, we shall learn little of either if we haughtily and peremptorily dismiss any of the elements out of the inquiry. Neither Nature nor Man is to be understood without God, nor can God be apprehended by pure intuition alone, or, save as he writes his hieroglyphics in objects and events, or imparts new impulses of goodness to the innermost soul. Tyndall, doubtless, caught a glimpse of the inseparableness of these elements when he said, "The passage from facts to principles is called induction, which, in its highest form, is inspiration,"[1] nor was he free from the same overshadowing truth, when, speaking of the possible solution of the ultimate physical problem, he remarks that, when it comes, "it will be one more of spiritual insight than of observation."[1] For, if deity be, as it is sometimes said, the Spiritual Sun, the intellectual Light, he may evade scrutiny, as the common light evades vision. It is the condition of vision, "the light of all our seeing," in which all objects are seen, though itself unseen. Besides, we know that, even in the common light, there are rays which the physical eyes do not see, which the inward eyes of reason alone behold, but which, if the physical eyes could be made sensitive to their swift pulsations, might disclose, according to Tyndall's exquisite suggestion, a new heaven and a new earth, immediately around us, and "as far surpassing ours as ours surpasses that of 'the wallowing reptiles which once held possession of this planet."

Science must not deny the finer rays which she cannot see; she may remain indifferent to them if she pleases, and is, indeed, largely obliged to remain indifferent because of the very conditions under which she works; but, while delving in matter, there is no reason for getting suffocated by its gases, or stifled in its mud. For, in that event, the narrowness and dogmatism you impute to "the classes still called educated," to "the cultivators of sentimental literature," and to "college-bred people," would be most unquestionably hers; the opposition to freedom and progress of thought that you deplore would be hers; and she would lose at once that devotion to truth, whithersoever it may lead, which is now her proud boast. Indeed, as I observe the world, pretension and bigotry are not confined to the circles where you discover them; there are so-called men of science who partake the fault; and who set up their own little area of outlook for the sum of God's measureless world. There are those who, because they may have attended a course of lectures on mechanics, or compiled a treatise on heat, or performed a few simple experiments in chemistry, assume, not that wisdom will die with them,

[1] "Fragments of Science," p. 60.

[1] Ibid., p. 100.

but that it was born with them. On the strength of these superior qualifications, they waive aside all the struggles of man after truth, in the past, as so many distempered dreams, which are about to be dispelled forever, because they have lit up a few farthing candles. Or, as a Buddhist poet says, "they are like infants born at midnight, who, because they see a sunrise, think there was never a yesterday." Let you and I, Mr. Editor, not be of the number. Let us be assured that some truth has come a good while ago, that it is coming still, in many ways, and will come in broader and rosier flashes in the future, though not to him who ostrich-like buries his head in the sand, or muffles his eyes against any of its illuminations.

I have the honor to be
Your obedient servant,
PARKE GODWIN.

MOMMSEN'S HISTORY AND THE STONE AGE IN ITALY.

MR. EDITOR: In Mommsen's "History of Rome"—one of the greatest intellectual productions of the age—vol. i., p. 30, American edition, occurs the following passage: "Nothing has hitherto been brought to light to warrant the supposition that mankind existed in Italy at a period anterior to the knowledge of agriculture and of the smelting of metals; and, if the human race ever within the bounds of Italy really occupied the level of that primitive stage of culture which we are accustomed to call the savage state, every trace of such a fact has disappeared."

Surprised at such a passage in such a book, I read it repeatedly, to be sure of its meaning. It seems to be plain enough. The statement is unwarranted; and, seeing that it is a negative one, it could hardly have been justifiable at the time it was written—probably twenty years ago. But, however that may be, it is certainly an oversight to retain it in the later editions without explanation.

Traces of early peoples who were savage in the extreme are plenty in many parts of Italy, even in the vicinity of Rome. Primitive stone weapons abound at Ponte Molle, Torre di Quinto, and Acqua Traversa, on the right bank of the Tiber. They are found in Liguria, and everywhere in what was Middle Etruria. Flint weapons of the rudest type are found in the lowermost beds of lava in ancient Latium. The like traces of a savage population are found at Imola, Casalvieri, and Alatri, in the neighborhood of Naples; at Ascoli, near Ancona; on Mount Brandon, in the vicinity of Ascoli, and on an island near Monticelli; in the territory of Borgo Ticino, on the plain of Vercelli-Borgo, and in the turf-pits of Mercurago and San Giovanni; in the region of San Germano, near Pinerolo, between the Tarnaro and Barrido, and on the right bank of the Agogna, in the territory of Briga; and in many other localities.

These relics consist mostly of hatchets and arrow or javelin points of flint and common greenstone. They are of all grades of workmanship, from the most rude to the most polished, and such is the variety in this respect that B. Gastaldi, who has thoroughly studied the specimens, believes that, if the usual division of the Stone Period into the Palæolithic and Neolithic (rough and polished stone) Ages be admissible, these relics would justify a further division of the Neolithic into two ages, according to the grade of workmanship.

Prof. Issel believes the evidence quite sufficient to show that the Ligurians remained stone-using savages, without knowledge of the metals, up to the time of their subjugation by the Celts and Romans.

It is trite to observe that unqualified statements resting wholly on negative support are unsafe. Still the learned continue to make them. This of Mommsen's reminds one of Rénan's archæologico-poetic assumption that the Egyptian civilization had no foreground of preparation. This appears very funny in the light of evolution. Whether the Egyptians were autochthones of the Nile or not, their civilization had a long period of beginnings just as certainly as the Hellenic had; and late discoveries, of what are believed by some of the highest authorities to be flint implements, indicate that Egypt was once inhabited by the rudest of savages. It is not safe to affirm of any spot on earth which has been long enough above water, that it has not been inhabited by people in the stone-using phase of life. J. S. Patterson.

Berlin Heights, Ohio.

"A SPIDER'S ENGINEERING."

Mr. Editor: The inquiry respecting the way in which spiders bridge chasms and streams, which is made in the note with the above heading, upon page 635 of the March number of this journal, has been often and satisfactorily answered by English writers,[1] and the following is given merely as a confirmation of their more extended observations:

In March, 1866, I had taken a living male and female *Nephila plumipes* (sometimes called the "silk-spider of South Carolina") to the photographic establishment of Mr. Whipple, of Boston; while waiting for the taking of their pictures, and standing about six feet from the wire frame upon which was extended the female's web, I saw the little male suddenly cease climbing about the frame, and take position upon its upper margin; in a few seconds a silken thread floated near me; I allowed it to adhere to my sleeve; the spider then turned about, and made several vigorous pulls upon the line, as if to ascertain its fixity of attachment; when satisfied of this, he rapidly made his way toward me, but, in order to observe the act again, I hung my end of the line over the frame, so that he was left where he started; after a few turns he took position as before, with his abdomen elevated and directed toward the spot I had occupied; presently a fine line shot out from his spinners, and pursued an undulating course until it reached beyond the spot I had occupied, and began to rise toward the large ventilating cupola in the centre of the room; the spider would occasionally turn and try the line as before, but it did not become attached, and he did not embark upon it.

Feeling now quite sure that the current of air toward the ventilator both determined the spider's preparatory action and the progress of the line, I removed this line, and blew gently upon the spider in the *opposite* direction; he immediately turned about, elevated the abdomen as before, *with the wind*, and soon a line was carried in this direction for as long and as far as my breath could reach, *and no farther*. This was repeated with the same result in various directions. The extremity of the line appeared blunt and a little enlarged, which is in accordance with the view of Blackwall respecting the way in which it is started:

"The extremities of the spinners are brought into contact, and viscid matter is emitted from the papillæ; they are then separated by a lateral motion, which extends the viscid matter into filaments connecting the papillæ; on these filaments the current of air impinges, drawing them out to a length which is regulated by the will of the animal, and, on the extremities of the spinners being brought together, the filaments coalesce, and form one compound line. . . . If placed upon rods set upright in glass vessels with perpendicular sides, and containing clear water, they in vain attempt to escape from them in a *still atmosphere*. . . .

"The lines produced by spiders are not propelled from the spinners by any physical power possessed by those animals, but are invariably drawn from them by the mechanical action of external forces."

It is not so very strange that an American journal should reproduce the note which suggested this communication, without incorporating the desired information, since very few papers upon spiders have appeared in this country; but the conductors of *Hardwicke's Science Gossip*, in which it first appeared, must have been strangely oblivious of the already-quoted English accounts of the subject.

But this oversight is pardonable when compared to what occurred in *Scribner's Monthly* for May, 1872, in an account of spiders, evidently a compilation. The common garden spider is represented *head upward* in the centre of a web composed of *concentric circles*. Now, every one that has really examined a so-called geometrical web knows that it consists of a *spiral line*, and *never of circles;* and also knows that the *Epeiridæ* are as averse to reposing head upward as human beings are to assuming the

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[1] Blackwall, "Spiders of Great Britain and Ireland" (Introduction, p. 11); Journal of Proceedings of Linnæan Society, vol. vii.; Transactions of Linnæan Society, vol. xv., p. 455.

reverse position; they invariably hang in the web *head downward.*

Surely it is a little incongruous that a magazine which lectures THE POPULAR SCIENCE MONTHLY for occupying too much space with such "pseudo-science" as that "most high-flown speculation," Evolution, should expend money as well as space for an engraving which is not only controverted by every accurate observation, but which might have been corrected by a glance into Webster's Unabridged.

BURT G. WILDER.

EDITOR'S TABLE.

SCIENTIFIC NORMAL SCHOOLS.

THE idea suggested by this title has long been with many a matter of vague and distant anticipation; but there is promise that something of the kind may soon become a realized fact. Rather, perhaps, we are to have a high-class Teachers' Institute on a strictly scientific basis. Professor Agassiz is expected to open, next summer, a school of natural history for the benefit of teachers during their vacation. He has associated with him twenty professors of high character to carry out the plan, and the object is, to afford ample facilities for studying specimens and becoming familiar with the actual properties and relations of living things. In an address before a committee of the Massachusetts Legislature on the claims of the Cambridge Museum of Comparative Zoology, Prof. Agassiz explained the nature and purpose of the contemplated project, which is kindred to the object for which the museum itself was founded. Education must have its storehouses of implements. For philosophy, history, and literature, public libraries are established, because these subjects are to be studied by means of books. But, in science, books are not sufficient; specimens are indispensable. We want, said Prof. Agassiz, to educate men who shall be able to read Nature, and this can only be done by studious familiarity with natural objects. The school is to carry out this plan. Nantucket Island has been selected as the location, and provision is made for a very thorough and comprehensive course of instruction.

This idea is certainly capable of extension, and the time, we think, has come when it should be taken up and carried out in different parts of the country. The Nantucket scheme could not be copied in the interior, because one-half of its subjects pertain to the natural history of the sea. The scheme is constructed from Prof. Agassiz's point of view, and is devoted mainly to zoology. The botany of land-plants is not included; entomology gets but little attention, and physics none at all. This is not intimated as a deficiency of the programme, which is sufficiently broad, and lays out more work than there will be time to do it in. It is evidently designed for the advantage of professors and teachers of science in educational institutions who already know something of the subjects, and desire the opportunity of perfecting their knowledge of natural history under the ablest instructors.

But the time has come for entering upon similar arrangements in behalf of the multitude of teachers in our common schools. We have normal schools for their preparation, but they are fashioned upon the old academic and collegiate pattern, and furnish only a book-education. The little science they pretend to give is book-science, and not the knowledge of things. Throughout nearly all of the common schools of the country, physics, chemistry, botany, and zoology, are taught, if taught at all, by the same method as history or Latin—that is, by committing and reciting lessons from books. It is universally admitted that this is absurd, but what to do about it is the difficulty. The system is self-perpetuating. The normal schools go on in the old ruts, and continue to furnish teachers of the old type. Higher standards of attainment may be exacted in the routine branches, and there is unquestionably some improvement in methods; but little is done to bring the minds of pupils into familiar relations with Nature. Scarcely any thing is done for the thorough cultivation of the observing powers by exercising them upon objects and experiments. In response to the demand for studying Nature, we have only the rude expedient of object-lessons for children, administered by teachers who know nothing of physical science on the one hand, nor the science of the growing mind on the other.

What we want in every State in the Union is what Prof. Agassiz is preparing to supply in Massachusetts, an opportunity for teachers to come together, where there are cabinets, laboratories, specimens, and experiments, and an able corps of instructors who are at home with all these resources, and can teach directly from Nature herself. If the vacation-weeks only are to be devoted to this work, the scheme of studies will require to be drawn up with strict reference to their urgent and practical requirements. Nantucket will be favorable for studying the zoological productions of the sea; but Nature is an inexhaustible museum, and every place abounds with the material for the illustration of scientific study. The air, the fields, the woods, and the streams, swarm with life; the rocks are uncovered, minerals abound; the earth is carpeted with vegetation, the forces of Nature are ever playing around us, while every family, school, church, factory, poor-house, jail, neighborhood, and village, affords materials for the scientific study of social phenomena and laws. What is needed is, to teach teachers to bring their minds to bear directly upon those things, to observe, compare, and analyze them, so that their knowledge may be real, positive, and worthy the name of science. It may not be easy to found a proper curriculum for a scientific teachers' institute, selecting just the proper subjects, and assigning them their due proportions; yet the work is entirely practicable, and experience would soon fix the adjustments. As a preliminary step to such a movement, nothing could be better than a national convention of teachers, professors, and school superintendents, called for the distinctive purpose of laying down the plan and organizing the means for the promotion of scientific education. Prof. Agassiz has broken the ice, and will show us what it is possible to do in this direction during a single vacation. His enterprise is a national movement, and at once raises the important question as to how similar advantages may be gained for the general education of the country.

Since the above article was put into type, an important change has taken place in Prof. Agassiz's programme. He has been presented with an island as a location for his school, and with a $50,000 endowment to assist in defraying its expenses. The donor is Mr. John Anderson, of New York, and the island of 100 acres, known as Penikese, is one of the Elizabeth group, near New Bedford, four miles from the main-land, and twenty-four miles from Newport. It has been the summer residence of Mr. Anderson, and contains such buildings and improvements as a wealthy occupant would construct for purposes of residence. What the effect of this change will be upon the original plan is yet problematical, but it can hardly fail to be considerable. We see it stated that $30,000 additional is required to erect suitable buildings, and $200,000 more to raise the endowment to the point necessary for carrying out Prof. Agassiz's plans. If these arrangements be consummated, a Natural History school of high character and large usefulness cannot fail to be the result. How far it will be organized in the interest of original scientific investigations, or in the general interests of education, or to what degree both objects will be combined, remains to be seen. It is to be hoped that Mr. Anderson's generosity will prove contagious, and that not only will Prof. Agassiz be furnished with the funds he requires, but that men of wealth in different parts of the country will contribute to kindred enterprises in their own localities. For the organization of such Scientific Teachers' Institutes as we have suggested, large sums of money would not be required. Buildings can be found suitable for school sessions, lectures, and demonstrations, and no care or outlay would be necessary to provide for the living of students and professors. The expenses to be incurred would be only for the liberal remuneration of the professorial corps, and for the various scientific appliances needed to illustrate the teaching. The project is feasible, if there is sufficient interest in the subject to carry it out.

MR. GODWIN'S LETTER.

We publish an able communication from Mr. Parke Godwin, called forth by our strictures, in the April Monthly, on his speech at the Tyndall Banquet, and restating, with more fulness, the views there expressed. With much that he says we cordially agree, and, had the position to which we mainly objected been originally stated as it is now, there would have been less occasion for criticism. In his address, after some remarks on the great results of modern science, Mr. Godwin said: "But it is real science, with its rigid restrictions to its own sphere and its exact methods, and not any pseudo-science, that will accomplish these grand results." He then gave examples, and classed among them the doctrine of Evolution as interpreted by Herbert Spencer. But, in his present communication, Mr. Godwin admits that "the nebular, the Darwinian, and the Spencerian views are hypotheses quite within the domain of scientific theory, and capable, to a certain extent, of explaining the phenomena to which they refer." He allows their legitimacy, which is what we contended for; but he denies that they are fairly-accredited scientific truths, and here we suspect he is again mistaken.

What, then, are we to understand by scientific truth? Mr. Godwin inventories the chimeras of the past, and, pointing to the *débris* of abandoned theories which strew the road of science, admonishes us not "to be too confident that our little systems of natral law will not, like other systems of thought referred to by Tennyson, have their day." The lesson is a wholesome one; but are scientists the parties that most need it? Is it they that are forever affirming "finalities," "absolute verities," and "eternal principles?" In what school are men so trained to distrust themselves, and to hold their views subject to constant revision, as in the school of science? Is it not ever seeking to supersede existing truth by larger truth? Chemistry reposes upon its ascertained elements, but chemists are prepared to see them at any time abolished or resolved into a single one, and in that case the gentlemen of the laboratory would be the first to throw up their hats in exultation. Even the principle of gravity is not held as a finality: Faraday labored for its reinterpretation, and, should it disappear in some larger generalization of dynamical law, physicists will not go into mourning. In science, the passing away of systems is generally an absorption of lesser into more comprehensive laws. The question of the truth of a new scientific theory is not as to its everlastingness, but as to its superiority to the views it seeks to supersede. Does it involve fewer assumptions? Does it account for more facts? Does it harmonize conflicting opinion? Does it open new inquiries and incite to fresh research? These are the tests that determine the acceptance of the theory, and, if it fulfils these conditions, it is held to be true.

Now, how does the doctrine of Evolution answer to these tests? It has arisen as an outgrowth of the latest and highest knowledge, has steadily made its way, in the teeth of inexorable criticism, to a large acceptance among the most disciplined thinkers of the period. It has been simmering in the minds of men of science for a century, and has now reached a point where it is capable of being formulated; where it is of great and acknowledged value for the guidance of scientific exploration, and it thus answers to the highest uses of theory. It is, moreover, becoming every day increasingly consonant with facts in the various branches of science, and is now far more congruous with the state of knowledge than any other hypothesis yet applied to the range of facts which it attempts to explain. The proof of the theory is unquestionably incomplete, but all theories are accepted under the same conditions. At the worst, it stands to-day where the theory of gravitation stood in the time of Newton, which, as Baden Powell remarks, "was beset by palpable contradictions in its results till many years after Newton's death."

On a complex and difficult scientific question of this kind, authority goes for something, and Mr. Godwin recognizes it. He remarks: "Can we say that any questions, on which such cautious observers and life-long students as Darwin, Owen, Huxley, Wallace, and Agassiz, still debate, are settled questions?" Certainly not; but, when their fundamental principles are accepted by four out of five of the eminent authorities which are cited as differing about them, we must acknowledge that the weight of authority is very strongly on one side. Nor is this all. The eminent scientific men who have adopted the view of Evolution, and that, too, against the powerful pressure of public prejudice, are to be numbered by scores and hundreds. In fact, the movement among naturalists, for the last ten years, toward a general doctrine of development, has amounted almost to a "stampede." This is not mere unsupported assertion. Here comes the latest scientific book of the season, "The Depths of the Sea," by the eminent Professor of Natural History in the University of Edinburgh, Wyville Thompson, and he says: "I do not think that I am speaking too strongly when I say that there is now scarcely a single competent general naturalist who is not prepared to accept some form of the doctrine of Evolution." Prof. Agassiz, indeed, still clings to his long-cherished opinions; but it is notorious that, on this question, his old students are running away from him, and his hypothesis, that there is an epidemic aberration upon this subject among the naturalists of the age, will hardly be held as a sufficient explanation of the phenomena. On the basis, therefore, of the judgment of the great body of those most competent to form an opinion, we cannot help thinking that Mr. Godwin was not only in error when he characterized the theory of Evolution as counterfeit science; but that he is also in error when he declares it to be a fugitive speculation, and not an accredited principle, entitled to the weight of valid scientific authority.

But, aside from the question of authority, Mr. Godwin argues against the validity of biological and psychological sciences on the intrinsic ground that they lack exactitude. It would have been a point gained for his argument to enforce the test of exactness, as then these sciences would pass under a cloud of discredit. But the test cannot be accepted. His method of criticism would throttle every science in its growing stages before completeness of demonstration had been attained. He insists upon a criterion which would abolish half the sciences and strip the remainder of all validity and authority except in their perfected forms. Referring to his address, he remarks:

"But then, I said—and it was the whole purport of my speech made in the interests of science as well as religion—that we can only expect these results from true science, which investigates what Nature really *is*, and not from a hasty and presumptuous science, which pretends to give us what Nature *may be supposed to be*. And my criterion of true science, suggested in a phrase, was, that the methods and results of it bear the impress of exactitude or certainty."

Now, nothing is more certain than that we can never arrive at what Nature really *is* except through the pathway of "what Nature *may be supposed to be*." All science begins with guesses and conjectures, and its most valid laws were at first but suppositions. The evidence by which scientific truth is determined necessarily involves suppositions to which it has been applied, and these have to be gradually confirmed; hence, if exactitude is demanded at the outset, all science becomes impossible.

To get at the full bearing of this matter we quote the original passage as it stands in the revised address of the proceedings at the Tyndall Banquet. It reads:

"Science is exact and certain, and authoritative, because dealing with facts, and the systematic coördination of facts only. She does not wander away into the void inane. She has nothing to do with questions of primal origin, nor of ultimate destinies; not because they are unimportant questions or insoluble, but because they transcend her instruments and her methods. You cannot measure love by the bushel, as the children say; you cannot catch fancy in a forceps to analyze its elements; you cannot fuse thought in a crucible to detect what may be dross, and what sound metal."

We think that Mr. Godwin here lends countenance to a prevailing fallacy. Science is perpetually bidden to keep within her sphere, and the popular notion of her sphere is that of experimentation. To most people the word science connotes physical or experimental science. On this tacit assumption Mr. Godwin declares that cubic measure, forceps, and crucibles, are not applicable to love, fancy, and thought. Most true; but will he maintain that these are therefore not amenable to scientific scrutiny? As we understand it, science is a knowledge of the constitution of things; of the uniformities of the phenomena of Nature. Whatever, in the universe around us, or in the world within us, is open to cognition, which can be examined and known, and reëxamined and verified, is the proper subject-matter of science, and the term is applied to all the knowledge that has been arrived at in this way. An emotion may be analyzed and understood as well as a mineral. Love, fancy, and thought, cannot be subjected to laboratory processes, but they may be known in their laws and relations as mental phenomena, and in this aspect they belong as strictly to science as metals or gases. That they cannot be weighed makes no difference, because exactness is not the criterion of science. Mr. Godwin asks, Where, then, does the inexactness come in? To which we reply, wherever the instruments, by which exactness is reached, are inapplicable, or can only be imperfectly applied. The best criterion of science is derived from the fact of order and uniformity in Nature by which one thing implies another, and we infer from what has been what will be again. It is *prevision*, that is, such a perception of the properties and relations of things as will enable us to see beforehand what effects will be produced in different times, places, and circumstances. Phenomena that elude measurement may yet occur with such regularity as to be foreseen with certainty. There is, in fact, a qualitative science which precedes quantitative, for properties must be known before they can be measured, but the test of prevision applies to the lower or qualitative stage as well as to the higher. Because biology, psychology, and sociology are not, and never can be, exact sciences, is therefore no reason for impugning their results as untrustworthy or without authority.

We quite agree with Mr. Godwin that Science is inexorably shut up in the finite and the phenomenal—the sphere of relation and law: but she must have the liberty of the whole domain. Nor do we think there is much danger of Science wasting her energies in trying to transcend these bounds, for she has plenty to do to get even partial possession of what confessedly belongs to her. She has won her ground, inch by inch, by hard fighting from the beginning, and even yet it is conceded to her only in name. Everybody will admit that it is the right of Science to inquire into all changes and effects in physical Nature. Yet, for suggesting that a given class of alleged physical effects be inquired into in the same manner as are other effects, Prof. Tyndall has been posted through Christendom as a blasphemer. Mr. Godwin yields to Science the realm of the finite and the relative, and in the same breath he speaks of the relations of Mozart to the laws of music, and of Shakespeare to the laws of the human heart, as examples of the trans-phenomenal. But we thought laws and relations had been made over to science. No reservation will here be tolerated. Science is providing for its ever-increasing army of research through a long future. Half a thousand years have been spent in getting on the track; another thousand will suffice to get under headway; she stipulates now only for room. Her sphere is the finite, but the nebulosities of ignorance must not be mistaken for the walls of the infinite. If mystics will lose themselves in the tangled recesses of unresolved phenomena, they must expect to be hunted out and have the place reclaimed to order and annexed to the provinces of all-harmonizing law. Nor can any pretext that they are nested in the unapproachable essences and subtleties of being, and ensphered in the absolute, and guarded by cunning sphinxes, avail them. The thing must inexorably be inquired of. It is the destiny of Science to pierce the unknown; if her spear is blunted upon the unknowable, she will of course accept the results of the experiment.

But, though scientists are hopelessly closed in, Mr. Godwin does not despair of others getting out, and he asks: "Is thought, whose expatiations are so restless and irrepressible, to be forever shut up to the phenomenal and relative? Is it to be forever stifled under a bushel-measure, or tied up by the legs with a surveyor's chain?" But the phenomenal and the relative go a great ways. Mr. Godwin talks as if "God's measureless world" were a stifling prison. We have been reminded that "Nature is a prodigious quantity," and we are so strongly impressed with this truth that we do not like Mr. Godwin's figure of a "bushel-measure" to symbolize its extent, any more than we like his favorite figure of "mud" to symbolize its quality. As to his question whether thought is to be tied by the legs with a surveyor's chain, we suspect that it is "tied" by something a good deal stronger than that: namely, by the laws of its own nature. He is skeptical about the science of psychology, and asks for its agreements. The question we are now considering may be taken as an example. It is pretty well agreed by the latest schools that, as the universe exists in relations, so thought is carried on in relations, and, by its very constitution, cannot transcend them. It is agreed that as music in all its inexhaustible complications is still made up by the combination of simple wave-pulses, so intelligence, in all the range of its complications, is made up of the combination of perceived relations; and we might as well talk of the higher exploits of musical art as transcending the vibrations of which they are constituted, as of the "restless expatiations" of thought transcending the relations of which mind is constituted. Sir William Hamilton is fair authority, and he says: "Limitation is the fundamental law of the possibility of thought. For, as the greyhound cannot outstrip his shadow, nor the eagle outsoar the atmosphere in which he floats, and by which alone he may be supported; so the mind cannot transcend that sphere of limitation within and through which exclusively the possibility of thought is realized." We therefore fear that, should any adventurer break bounds on a winged horse, and take his flight through the ultra-phenomenal tracts, the tidings wafted back would prove altogether unintelligible.

Mr. Godwin says: "Am I to infer from your objections to my remarks that The Popular Science Monthly holds materialism, atheism, and naturalism, to be the legitimate outcome of science?" Exactly the contrary. We do not believe that the legitimate outcome of science is materialism or atheism, and our attempt was to show that certain problems and procedures, which Mr. Godwin declared to be spurious science and obnoxious to these charges, were genuine science, and not obnoxious to them. We objected, in order to rescue a portion of science from an aspersive charge to which all science is equally liable. Büchner may be a materialist, and Comte an atheist, and Taine may be both, although it does not follow, because he affirms the correlation of mind with nervous motion, that he is either. What moved us to protest was the gross injustice of branding Mr. Spencer's expositions of the doctrine of Evolution as sham science, and then loading it with the opprobrium which its associations and the argument implied. Of Spencer's system, Mr. Godwin says, on his own and higher authority, that it is "full of unsupported assumptions, logical inconsistencies, and explanations which explain nothing, while in its general character it tends to the sheerest naturalism." We do not deny that it contains defects—it would be, indeed, surprising if so vast and original a discussion did not; but to say that it is "full" of the vices alleged, or that they characterize it, is a reckless exaggeration. As a set-off to this opinion, we refer the reader back to page 32, where he will find the latest estimate of Mr. Spencer's philosophy by a man who is an authority upon the question he discusses.

As to the religious "tendencies" of the system, although they are charged with being all that is bad, and although the charge would undoubtedly be sustained by a popular vote, we are of opinion that it is bound to be very differently viewed in the future. Mr. Spencer is a profound believer in religion, and at the very threshold of his system he has shown the ultimate harmony of science and faith. Yet he has not tried merely to patch up a transient truce between religion and science; but, foreseeing the intenser conflicts that are inevitable as science advances, he has labored to place their reconciliation upon a basis that no extension of knowledge can disturb. When the method of science is raised to its rightful supremacy in the human mind, and the rule of science is recognized as supreme throughout the sphere of the phenomenal, and when the distractions of theology become unbearable, it will then be found that Mr. Spencer has proved that science, so far from being its destroyer, is itself the promoter of the profoundest faith, while the central truth of all religion is saved to humanity. Malignant zealots will probably continue to secrete their vitriolic criticism, as, if stopped, they would probably die of their own acridities; but there are not wanting indications that many religious men of candor and discernment are already recognizing the claims of Mr. Spencer's system upon the serious consideration of their class. For example, a late number of the *Nonconformist*, the organ of the English dissenters, and an orthodox paper of high influence, says of Spencer: "He is not an idealist, nor is he a materialist. Like Goethe, he believes that man is not born to solve the problem which the universe presents." Yet the writer holds his views to be of very great importance, and speaks of it as "an importance, in our opinion, so great, that the future, not only of English philosophy, but of practical theology, will be determined by its acceptance or rejection."

As for ourselves, differing widely from Mr. Godwin in his estimate of Spencer's system of philosophy, we record our opinion that, as it becomes more fully known, it will be recognized as an unequalled performance in its rigorous conformity to scientific method, and as the first grand alliance of science and philosophy; that it will exert an all-reconciling influence upon the chaos of doctrine; that, while based upon progress, it will prove powerfully conservative, and will leave all other systems behind in its value for guidance, both to the individual and the state. We believe that the time is not greatly distant when even theologians will seek it as a shelter against the rising tide of "materialism" and "atheism;" and, finally, we predict that, if Mr. Spencer lives to complete his "Principles of Sociology," with the accompanying tabular scheme of "Descriptive Sociology," that which Mr. Godwin says is now only a "hope" will become an assured and authoritative science—which is certainly one of the most imminent desiderata of civilization.

LITERARY NOTICES.

Education in Japan. A Series of Letters Addressed by Prominent Americans to Arinori Mori. New York: D. Appleton & Co., 1873. 255 pages.

And now Japan comes forward to confound the theories of publicists, and give a new problem to political philosophers. An ancient Oriental nation, with a history stretching over 2,500 years, and claiming the oldest dynasty in the world, containing 34,000,000 people, and which has long been shut out from the world by its exclusive system, now throws open its gates to intercourse with other nations, and raises the great question as to how it may best acquire the highest benefits of civilization. Its youths are sent away to be educated (there are some 300 in this country), and learned foreigners are sent for, that the modern arts and sciences may be acquired, and there are even indications that this proud and exclusive people meditate a change of language, and the adoption of English in place of their native speech. The Japanese envoy at Washington, Mr. Arinori Mori, a liberal and well-educated young gentleman twenty seven years of age, has addressed a circular letter to a large number of the distinguished men of this country, asking their views and advice as to how the Japanese can best gain the advantages of education, free commerce, and enlightened industry, and best improve the social, moral, and physical condition of the Japanese people. The present volume embodies the replies which he received from Presidents Woolsey, Stearns, Hopkins, McCosh, Eliot, Profs. Seelye, Henry, Murray, Northrup, Whitney, the Rev. O. Perinchief, and the Honorables G. S. Boutwell, J. A. Garfield, and Mr. Peter Cooper. Their replies are not only interesting as furnishing the information required for its practical objects, but they are also interesting as illustrating the way American scholarship engages with this novel and curious sociological problem. Mr. Mori has prepared an introduction to the volume, giving an historical sketch of Japan, and some account of the present condition of its government, religion, language, and people.

Diseases of the Urinary Organs, including Stricture of the Urethra, Affections of the Prostate, and Stone in the Bladder. By John W. S. Gouley, M. D. With One Hundred and Three Wood Engravings. New York: William Wood & Co., 1873.

Amid the flood of medical works annually poured out for the doctor's guidance, it is a pleasure to find occasionally one that deals, in a clear and straightforward way, with the subject in hand, and is not encumbered with the endless theories and speculations of which medical writers are so prolific. The book before us is one of these exceptional productions in medical literature. It is in no sense a compilation, but embodies the results of an extended experience, both in private practice and in the hospitals of this city. Yet, while thus mainly founded on personal observation, the claims and teachings of the many eminent men who have illustrated this department of surgery have not been overlooked. The author does not undertake to go over the whole of this important department of medicine, but modestly limits himself to a few of the graver surgical affections of the male urinary organs, giving the pathology, clinical history, and treatment of each, with full and explicit directions for the various operations involved. Whenever the use of instruments is called for, he urges, with emphatic earnestness, the necessity for the utmost care in their employment; and this, to our minds, is not the least valuable feature of the book, since it is well known that these and other diseases are often seriously aggravated, and not unfrequently put beyond the reach of cure, by the bungling manipulations of over-confident and careless operators. Dr. Gouley's abilities as a practitioner are unquestioned, his success as a teacher has also been amply proved, and the present work gives evidence, both in matter and style, that he is entitled to rank equally high as a clear and instructive writer.

The Microscope and Microscopical Technology. A Text-Book for Physicians and Students. By Dr. Heinrich Frey. Translated from the German, and edited by George R. Cutter, M. D. New York: William Wood & Co., 1872.

We welcome the appearance, in an English dress, of Frey's excellent work. It covers a far wider field than Martin's book, noticed in a recent number of The Popular Science Monthly; indeed, the entire subject of microscopy and microscopical instruments is treated by Dr. Frey. The author devotes one-third of his work to the description of microscopic instruments, the testing of them, and their uses. To the section on "Testing the Microscope," the translator appends a few pages of original matter, giving the history of microscope-manufacture in the United States. He shows that microscopes of American manufacture possess all the excellences of foreign instruments, *plus* certain mechanical simplifications the product of American inventive genius.

The "Preparation of Microscopic Objects" has nearly 250 pages devoted to its treatment. This is a very important branch of the *technique* of microscopy, and the student will find here all the practical directions he needs, derived from the experience of the most eminent microscopists. The purpose of this portion of the work, as also of the section on "Mounting," is to save the student countless mortifying failures. Every microscopist may discover for his own use the best processes for preparing and mounting; but the time so spent is better spared, and devoted to practical investigation. The work of the microscopist is at all times exceedingly laborious, requiring a degree of patience and application that is almost incredible. The author aims in this part of his book to smooth away some of the difficulties attending the first approaches to this fascinating study; but, if any *dilettante* expects to find here a royal road to microscopy, he will be most assuredly disappointed. Of this branch of knowledge, it is preëminently true that only by hard work can any progress be made. This portion of the work is of high value, and the information it contains is nowhere else accessible, at least in the English language.

The remaining 400 pages are devoted to explaining the mode of investigating the fluids and tissues of organisms, etc. The author's method here is, first, to ascertain the normal conditions of tissues, organs, etc., and then to study diseased conditions, the pathological structure always more or less repeating the normal. As far as we have had an opportunity of judging, the translator's work appears to be well done.

The Depths of the Sea. By C. Wyville Thompson, LL. D., etc. London and New York: Macmillan & Co., 1873.

Certain new and very interesting results, in regard to the distribution of life, have been arrived at within the last few years, by dredging the bottom of the sea. Twenty years ago it was believed that at certain depths the greatness of the pressure, the lowness of the temperature, and the deficiency of light and aëration, made it impossible for life to subsist. The alleged cases of living creatures being drawn up from these great depths were discredited. The operations of cable-laying and cable-raising have, however, increased our familiarity with the bottom of the sea, and the improved manipulations have been turned to account in exploring its life. The result was, the establishment of the truth that there is an order of life belonging to the sea-bed in the profound abysess of the ocean. The recognition of this fact led to systematic attempts to carry on deep-sea explorations. In 1868 the steamer Lightning was placed by the British Government at the disposal of Dr. Carpenter and Mr. Wyville Thompson for the express purpose of submarine research, and the Porcupine was afterward assigned, for a more extensive series of surveys, to the same gentlemen, with the addition of Mr Gwyn Jeffreys, in the summers of 1869 and 1870. In the first of these cruises the greatest depth reached was 1,500 fathoms, but in the second they went to the depth of 2,500 or 3,000 fathoms. The present volume is a record of the results attained in these expeditions. It gives an account of the apparatus and instruments employed, of the forms of organization discovered, and much information regarding the physics of the ocean. It is splendidly illustrated and popularly written, with much humor, and the treatment, like the subject, is any thing but dry; it is a volume altogether worthy the interest and importance of its subject.

Van Nostrand's Eclectic Engineering Magazine. New York: D. Van Nostrand, 23 Murray Street.

We call the attention of mechanics, engineers, manufacturers, and scientific students, to this able and valuable periodical, now in its eighth volume. It treats of the applications of science, constructions, mining, and technical processes, and gives the solid literature of these subjects from all sources. It is edited with excellent discrimination, and the bound volumes of the series would form a most useful cyclopædia of recent authentic information upon the subjects to which it is devoted.

Historical Statement of the Business and Condition of the Mutual Life Insurance Company, of New York, for Thirty Years, from 1843 to 1872.

The company did well to state, in the beginning of this pamphlet, that its matter is important; since, owing to the style in which it is presented, few will be likely to discover that fact in any other way. Its contents are put in the shape of a facsimile of the original statement, signatures and all, a form to which probably not one in a hundred will attach any special value, and that involves a useless waste of time and patience on the part of the reader. What policy-holders and the public want is clear and explicit information that is readily accessible, and this appears to be just what the insurance companies are unable or unwilling to furnish.

Hygiene: a Fortnightly Journal of Sanitary Science. New York: Putnam. Two dollars per year.

This is a publication that was much needed, for the first of all our interests, that of health, is the one concerning which people are most careless and indifferent. It is amazing the amount of ignorance displayed, even by cultured people, with regard to the most evident precepts of sanitary prudence. This journal will, no doubt, do a good work in helping to diffuse abroad something like rational views as to the *conditions of health.* This periodical has nothing directly to do with medicine, nor will it attempt to make doctors of its readers. *Hygiene* is handsomely printed and carefully edited.

MISCELLANY.

Meteor-Showers on the Night of November 27, 1872.—In all quarters of the heavens, says an astronomical periodical, the *Leipziger Sternwarte*, the meteors were very numerous, especially in the Southwest and the Northeast. An observer looking toward the South counted within 54 minutes, soon after seven P. M., 700 meteors; another observer 807 meteors in 40 minutes. Between eight and nine o'clock 899 meteors were counted in 42 minutes, 304 in 19 minutes between nine and ten o'clock, 291 in 30 minutes between ten and eleven o'clock. Now, as the observer could view about one-fourth of the heavens, and as over 20 meteors per minute were observed at about eight o'clock, we must set down the number falling between seven and eight, and between eight and nine, at 5,000 per hour. The phenomenon began to fail at ten o'clock, and, between that hour and eleven, only 2,000 meteors fell. About one-sixth of these meteors were brighter than stars of the first magnitude, and many of them left a train which was luminous for several seconds. The majority of them were, however, between the second and fourth magnitudes. In color most of them were yellow, though some were green, some blue, some red; those of feebler lustre were white. Prof. Galle, of Breslau, and Prof. Klinkerfues, of Göttingen, agree in attributing this meteor-shower to the meeting of the earth with Biela's comet. "Without doubt," writes the former, "these meteors consist of scattered particles of Biela's comet, meeting the earth, as that comet in its septennial period passed that point in its career in the beginning of September, and was at its perihelion at the beginning of October. Schiaparelli's discovery of the connection between comets and meteoric showers thus obtains fresh confirmation."

Professor Agassiz's School of Natural History.—This establishment, which was at first designed for Nantucket, but is now intended for Penikese Island, had the following programme of subjects and instructions:

"1. Zoology in general, and embryology of the vertebrates, by L. Agassiz, Director of Museum. 2. The extinct animals of past ages compared with those now living, and the methods of identifying them, by N. S. Shaler, Professor of Paleontology at the Lawrence Scientific School. 3. Comparative anatomy and physiology of the vertebrates, by Dr. B. G. Wilder, Professor of Anatomy and Physiology at Cornell University, Ithaca, N. Y. 4. The animals and plants living in deep waters, and the peculiar conditions of their existence, by L. F. de Pourtales, of the United States Coast Survey. 5. Embryology of the radiates, by A. Agassiz, of the Museum of Comparative Zoology. 6. Natural history of embryology of the mollusks, by Prof. E. S. Morse, of Salem. 7. How to make biological collections illustrative of the history of insects injurious to vegetation, by Dr. H. A. Hagen, Professor of Entomology at Harvard University. 8. Natural history and embryology of the articulates, by Dr. A. S. Packard, Jr., Curator of Articulates at Peabody Academy of Science, Salem, and Lecturer on Entomology at Bowdoin College. 9. Natural history of the fishes and reptiles, by F. W. Putnam, Director of Museum of Peabody Academy of Science, Salem, and Permanent Secretary of the American Association for the Advancement of Science 10. Natural history of birds and mammals, by J. A. Allen, of the Museum of Comparative Zoology. 11. On breeding, and nests and eggs of birds, by Dr. Thomas W. Brewer, chairman of Committee on Birds, Nests, and Eggs, of the Boston Society of Natural History. 12. Practical exercises in the use of the microscope, by Mr. Bicknell. 13. Instruction in drawing and painting of animals, by Paulus Roetter, Artist at Museum of Comparative Zoology. 14. On the preservation of our sea-fisheries, by Prof. Spencer F. Baird, United States Commissioner of Fisheries, and Assistant Secretary of Smithsonian Institute. 15. On fish-breeding, by Theo. Lyman, of the Museum of

Comparative Zoology. 16. The fauna of the North Atlantic, compared with one another, and with that of other parts of the world, by Prof. Verrill. 17. The plants of the sea, by Prof. Eaton. 18. The physics of the sea, by Prof. Joseph Lovering, Professor of Natural Philosophy, Harvard University. 19. Physical hydrography, by Prof. Mitchell, of the United States Coast Survey. 20. Chemistry of feeding and breathing, by Prof. W. Gibbs, Rumford-professor of Physics, Harvard University. 21. Chemistry of the sea and air, by Prof. James Crafts, Professor of Chemistry at the Boston Technological Institute."

The Causes of Typhus.—As causes predisposing to typhus, medical writers usually enumerate mental depression, anxiety, fear of contagion, intemperance, insufficient nutrition, and overcrowding. Now, during the sieges of Paris and Metz, the inhabitants of those two cities were subject in an extraordinary degree to all these conditions, if in the case of Metz we except the fourth; and yet not a single case of the disease occurred among either the citizens, the refugees, or the soldiers. The beleaguering armies of the Germans, on the contrary, whose sanitary condition was infinitely better, were constantly ravaged by typhus. This conflict of facts with theory has led Dr. Chauffard, of the Paris Academy of Medicine, to investigate the subject of typhus anew, and we here give the chief results of his inquiry. According to him, the epidemics of typhus which have broken out in France had always a foreign origin, and the disease has never been able to become endemic in that country. The epidemic of 1814 was brought in by the defeated armies of the North, on their return from Russia and Northern Germany, and that of 1855–'56 was imported by the troops returning from the Crimea. But soon they died out on French soil, and hence the author conjectures that in the French race and on French soil there is something which is antagonistic to typhus. He inclines to regard this disease as localized, so far as its origin is concerned, just like cholera, or yellow fever. Then, to show that his conjecture as to race immunity is not without foundation, he states that in New Orleans the yellow fever commits its greatest ravages among the whites, the cholera among the negroes. Then, too, the negro race can better resist the morbid influences of marshy soil, than can the white. To show how different may be the effects of the same morbific influences on diverse races of men, the author cites the case of an Egyptian vessel entering the port of Liverpool in the worst possible sanitary condition. The crew were all sick—but no typhus. But the Englishmen who visited the ship were nearly all seized with that disease. On the high table-lands of Mexico, typhus is endemic and frequent, typhoid fever very rare. On the contrary, at an altitude of less than 2,000 feet above the sea-level, typhoid is abundant, typhus rare. Even on the table-lands, however, newly-arrived French soldiers were attacked by typhoid; but, when they had become acclimated, they were seized only by typhus. The author replies to the objection that might be drawn from the occurrence of typhus in prisons and among convicts condemned to the galleys, by claiming that such outbreaks of supposed typhus are really only typhoid fevers of an unusual character. In fact, ever since French physicians had, after the Crimean War, an opportunity for more closely studying true typhus, prison epidemics are not often characterized as outbreaks of that disease. The author then examines certain cases where undoubted typhus has made its appearance spontaneously, as it might be supposed, on French soil, and explains the occurrence by importation from foreign countries. Our brief abstract is far from doing justice to this highly-important paper, and we commend the entire essay, as found in the *Revue Scientifique*, to the attention of our medical readers.

Habits of Right and Sperm Whales.—In the *American Naturalist*, Prof. N. S. Shaler notes some of the prominent characteristic habits of right and sperm-whales, on the authority of an old whaler, Captain John Pease, of Edgartown, Massachusetts. The calving-time for the right-whale, he says, never begins until July 1st, and by the 3d or 4th of the month every female is accompanied by her calf. The affection of the right-whale and of the humpback for their young is very strong, but the sperm-whale gives no evidence of such fondness. Among sperm-whales there is strict subordination of every herd to its leader, but each right-whale appears to be independent. The male right is smaller than the female, but the reverse is the case for the sperm-whale. The males of the sperm-whale engage in furious conflicts with each other, and Captain Pease has often found clear evidence of these fights in the scarred bodies of captured whales. In the Nantucket Museum may be seen two specimens of the lower jaw damaged in conflict, one of them being bent laterally into one turn of a spiral. Captain Pease has often witnessed the attack of the sperm on the right and humpback whale. Fifty or more of them will join in the attack, leaping many feet out of the water and falling on their victim. Squid forms the principal food of the sperm-whale, and Captain Pease once saw the head of a squid, as large as a sugar hogshead, which had been chopped off by the closure of the sperm-whale's jaws.

The captain is positive that a trace of hair is to be found within the skin of the right-whale, and says that, if the fresh skin be scraped, the inner section will show a trace of hair. If this whale is the descendant of a land-mammal, we should expect to find just such a trace of hair. Then, too, there is a sperm-whale's tooth at Nantucket which has two fangs, and it is stated that the other teeth of the animal to which this belonged had likewise two fangs. The author suspects here a case of reversion. According to Captain Pease, right-whales attain adult size in three years, though he admits that they may grow very slowly for some years longer.

Cruelties of the Seal-Fishery.—The cruel and useless destruction of young seals, resulting from the way in which the seal-fisheries are at present conducted, has called out a vigorous protest from Mr. Frank Buckland, coupled with a recommendation that the governments concerned unite in a system of regulations that shall in future prevent the barbarities and wastefulness which, if continued, must soon put an end to an important industry. On the authority of Captain David Gray, commander of the screw-steamer Eclipse, of the Scottish sealing-fleet, we are told that operations begin about the 20th of March, or within a few days after the young are born. The harpooner chooses a place where a number of young seals are lying, knowing that soon the mothers will make their appearance. Of these, as many as 40,000 were killed last year, not to speak of those that were wounded and scared away. Thus tens of thousands of young seals are left motherless. "It is horrible," says Captain Gray, "to see the young ones trying to suck the carcasses of their mothers, their eyes starting out of the sockets, looking the very picture of famine. They crawl over and over them until quite red with blood, poking them with their noses, no doubt wondering why they are not getting their usual feed, uttering painful cries the while. The noise they make is something dreadful. If one could imagine himself surrounded by four or five hundred thousand human babies all crying at the pitch of their voices, he would have some idea of it. Their cry is very like an infant's. These motherless seals collect into lots of five or six, and crawl about the ice, their heads fast becoming the biggest part of their bodies, searching to find the nourishment they stand so much in want of. The females are very affectionate toward their young." Immense numbers of young seals are in this way starved to death; and, even if slaughtered on the spot, are comparatively worthless, as their bodies contain little or no oil, and their skins bring but a very low price. According to Mr. Buckland, if the commencement of the work were postponed for only three or four weeks, the young would then be old enough to take care of themselves, and, even if killed, which he strongly objects to, at this early period of their lives, their bodies would have a greatly increased value.

The Failure of Car-Axles.—The fracture of car-axles, and the frequent accidents arising therefrom, are due, it appears, in the majority of cases, to imperfect construction, which may be readily detected by applying the proper tests. As an example of the kind of work that manufacturers sometimes turn out to railway companies, we are told by Mr. James E. Whitney, in the *Railway Times*, that, of a lot of axles furnished to the Mobile & Ohio Railroad Company, but one-fourth were capable of meeting the required test, and the other three-fourths were returned to the manufacturer. Mr. Whitney also says that the duty of making these tests belongs to the railway companies themselves, which leaves them no valid excuse for the employment of defective materials.

Besides the use of poor iron, the resisting power of the axle may also be lessened by the method of manufacture. "The ideal axle," says Mr. Whitney, "would have its metal as dense as possible, and hence would be shaped mainly by hammering. Its fibres would run unbroken throughout its length, and the tough outer skin, which in wrought as in cast iron is much stronger than that within, would be preserved in its integrity." As now manufactured, a portion of this is removed by turning, and the axle proportionally weakened. The turning process is also carried to the formation of sharp corners, which, as shown by Rankin, eventually become the starting-points of annular or circumferential grooves that continue to deepen until the central portion is too much diminished to bear the shock of the unusual jar: "The ordinary 'tapping' will, in aggravated cases, enable such a flaw to be detected, but no skill and no care will guard against the slow but sure approach of danger, because of the unnecessary removal of a few annular chips at the shoulder of the wheel-bearing, to gratify the whim of the turner."

But, however strong originally, car-axles always deteriorate with use, the constant succession of jars to which they are subject gradually impairing the strength of the iron. The character of this change is not well understood, and the only effective method now known, of guarding against the danger arising from it, is to throw the axle aside after it has been run a certain number of miles.

Bowlder-like Masses of Clay in Drift.—Masses of stratified gravel, similar in shape to the clay-bowlders mentioned in the March number of this monthly as occurring in the drift of Long Island, were found during the excavation of the Chicago Tunnel in the drift under Lake Michigan. In the *American Journal of Science* for January, 1867, Prof. E. Andrews thus describes them: "They lay in all imaginable positions, sometimes with their strata set up at high angles. They were from a few inches to a few feet in diameter, and were embedded in the solid, impervious clay nearly 80 feet below the surface of the lake. The gravel was water-worn, and often so clean that it would scarcely soil a handkerchief. The interstices commonly contained a few gallons of water in the lower part, and some air or gas in the upper. The gas was in many instances inflammable. The pockets scarcely leaked a drop when once emptied, and the cavities looked exactly, in many instances, like casts of rounded bowlders."

Prof. Andrews believes they were deposited as frozen masses which thawed after they were embedded in the clay. This view is corroborated by an experiment made two years ago by Mr. E. Lewis, of Brooklyn. During a period of cold weather he selected an inlet of the sea through which the tidal flow was rapid, and in which the water was several degrees below freezing. The bottom was frozen where the water was 10 feet deep, but there was no ice on the surface. A mass of frozen earth weighing about 50 pounds was sunk, by means of a cord, at the deepest part of the inlet. Six days afterward this mass was unchanged, except that its extreme surface was slightly soft and moist. At the expiration of 30 days it was again examined, and found to be somewhat wasted. The temperature of the water was then 3° above freezing. "If," says Mr. Lewis, "this mass had been covered by a quantity of sand or gravel, thrown down upon it while frozen, it would have retained its form; and enormous masses of such material are sometimes deposited suddenly from floating ice and glaciers."

Marked Case of Heredity in Mastiffs.—Mr. Darwin communicates to *Nature* a letter from Mr. Huggins on the hereditary transmission, in a breed of mastiffs, of a strong antipathy to butchers and butchers' shops. Mr. Huggins owns a dog, "Kepler," whose sire was a celebrated mastiff, "Turk." When "Kepler" was six months old he followed a servant out on the street, and then for the first time saw a butcher's shop. The animal threw himself down, and could not be induced to pass the place. The dog is now nearly three years old, and the antipathy has diminished somewhat, but not disappeared. Mr. Huggins lately found that "Kepler's" ancestor, "Turk," manifested the same antipathy, and his former owner was asked for information on the subject. It now appears that this curious dislike for butchers' shops and butchers was shown equally by "Turk's" sire, "King" (in whom it probably originated), and by "Punch" and "Paris," sons of "Turk." The antipathy is most marked in "Paris," who will hardly enter a street containing a butcher's shop, and runs away after he has passed it. If a butcher's cart comes to the place where the dogs are kept, they are filled with fright even though they do not see the object of their fears. "Turk's" owner, Mr. Nichols, then tells of two instances where "Paris" gave evidence of the most extraordinary sagacity in recognizing a butcher under any circumstances. One evening a boss-butcher, in ordinary clothes, called to see "Paris," but had scarcely entered the house when the dog became unmanageable, and the visitor had to leave without seeing him. On another occasion "Paris" sprang at a gentleman, and, as it was the first exhibition he ever had made of such viciousness, his owner apologized, and said that the dog had never before attacked any but butchers. The gentleman *was* a butcher!

Since the publication of Mr. Huggins's letter, several other communications have appeared in *Nature*, showing that all the dogs of this line inherit this instinctive antipathy. Mr. H. G. Brooke writes of a grandson of "Turk:" "Ever since he was a pup he has evinced" this antipathy. A brother of this dog of Mr. Brooke's shows the same feeling, according to Mr. Arthur Ransom, his owner.

Mr. Russel Wallace is inclined to think that these dogs distinguish butchers from other men by the sense of smell, which is very acute in all dogs. He also thinks that it it this sense which enables a dog to find his way back from a distance, though on first making the journey he had been blindfolded, and so prevented from seeing his way. Another correspondent of *Nature*, writing in confirmation of Mr. Wallace's view, tells of a cat's antipathy to dogs. This animal would "swear," if only stroked by a hand which had directly before touched a dog. Mr. Darwin's purpose in calling attention to the present case of heredity is, to illustrate his theory of instinct as an acquired and transmitted habit.

Changes in River-Beds.—In a report on the subject of a water-supply for the village of Yonkers, New York, published in the January number of the *American Chemist*, Prof. J. S. Newberry furnishes some interesting facts on the geology of river-beds, that will be of general interest. He says: "It is probably known to you that most of the draining streams of all the region between the Mississippi and the Atlantic are now running far above their ancient beds. This fact was first revealed to me by the borings made for oil in the valleys of the tributaries of the Ohio. All these streams were found to be flowing in valleys, once deeply excavated but now partially filled, and, in some instances, almost obliterated. Further investigation showed that the same was true of the draining streams of New York and the Atlantic slope. For example, the valley of the Mohawk, for a large part of its course, is filled with sand and gravel, to the depth of over two hundred feet. In the Hudson the water surface stands now probably five hundred feet above its ancient level—the old mouth of the Hudson and the channel which leads to it being distinctly traceable on the bottom nearly eighty miles south and east of New York The excavation of these deep channels could only have been effected when the continent was much higher than now. Subsequently it was depressed so far that the ocean-waters stood on the Atlantic coast from one hundred to five hundred feet higher than they now do. During this period of submergence the blue clays in the valley of the Hudson—the 'Champlain clays'—were deposited, and the valleys of all the streams were more or less filled."

Dimensions of New-England Glaciers.—The Glacial and Champlain Epochs in New

England is the subject of a learned paper, by Prof. Dana, in the *American Journal of Science* for March. From it we learn that in Northern New England the glaciers were from 5,000 to 6,500 feet in thickness. At the White Mountains the ice-surface was 6,000 feet above the sea-level, and the mass had a depth of nearly a mile. On Central Long Island the surface of the glacier was 2,100 feet above the surface of the sea, and in the Connecticut Valley 3,200 feet. The slope of the ice-surface from the White Mountains southward was about 24 feet to the mile, and about 19 feet to the mile in the Connecticut Valley. The glacier extended beyond the present coast-line, possibly some 90 miles southward of Long Island. Its forward movement is thought to have been one foot in a week, or about 100 miles in 10,000 years. The crushing and erosive power of such an enormous mass of ice may be appreciated when it is known that, if 6,000 feet thick, it would lie upon the earth with a pressure of about 300,000 pounds to each square foot.

NOTES.

A monument is to be erected in Birmingham, England, to the memory of Dr. Joseph Priestley. In his lifetime his heterodoxy disqualified him for a berth in one of Captain Cook's ships, though he would have been a most valuable aid to the commander. The time has at length come when England and America can do honor to the man who "embraced what is called the heterodox side of every question."

Five living sea-fish were recently sent by mail from Naples to London, the journey consuming a little over four days. The fish were each about two inches in length, and were packed in damp sea-weed, from which all but one came out in good condition, and, soon after being placed in their natural element, became as lively as ever.

Prof. Leidy is of opinion that contagion is frequently transferred from one subject to another by the agency of the common house-fly, and his observations in military hospitals have led him to the conclusion that flies should be carefully excluded from wounds, particularly if gangrene is anywhere about.

Weltwitsch tells of a plant, an oxalis, growing in Angola, Africa, which is so sensitive that it closes its leaves on hearing (so to speak) a footfall in its neighborhood.

A dying pauper in Ireland willed his body to a surgeon for dissection. The poor-law guardians are indignant, and demand that the surgeon, who is medical officer to the Board of Charities, resign. The ground on which it is sought to annul the pauper's will is, "undue influence." This is probably the first case in which a pauper's last will and testament is brought into dispute.

Berlin has grown rich by war, but her poor are growing poorer. About half of the population live in dens which have usually two chalk-lines crossing each other on the floor. A room is thus divided into four compartments, one for the sleeping-place, another for the nursery, the third is hired to a lodger, and the fourth is kitchen, living-room, and workshop.

A San Francisco paper says that oysters can be imported into California from Mexico at a cheaper rate than from New York. The coast of Mexico, from Guaymas to Acapulco, abounds in oysters of large size and excellent flavor. They can be put on board the Mexican steamers at Mazatlan, at less than $15 per ton, and the freight thence to San Francisco would not be over $10.

The following is in striking contrast to the "devil-may-care" policy of our laws in regard to the safety of railway-passengers: In England it is against the law to attempt to get on or off a railway-train while in motion, and, more than that, the law is enforced. Recently a young man nearly lost his life in the attempt to board a train which was slowly moving out of a station. He was brought up for trial, and fined five shillings with costs. A woman who stepped off a moving train was also convicted, and, having no money, was sent to jail for ten days. Americans, about to travel in England, may save some of their loose change and perhaps their personal liberty, by making note of this.

Prof. Voght records an instance of what may be called self-cannibalism. He cut in two a male cricket, and immediately the fore part, probably experiencing a sensation of emptiness in the ventral region, turned upon the hinder part and devoured it!

A French apothecary has discovered an excellent and very cheap substitute for quinine, in powdered laurel-leaf. The leaves of the laurel (*Laurus nobilis*) are slowly dried over the fire in a close vessel, and then powdered. One gramme (15½ grains) is a dose, and is taken in a glass of cold water. The drug so taken produces no bad effects, and soon, it is said, breaks up the most obstinate intermittent fevers.

THE

POPULAR SCIENCE MONTHLY.

JUNE, 1873.

THE CONSTITUTION OF NEBULÆ.

BY DR. H. SCHELLEN.[1]

WHEN the starry heavens are viewed through a telescope of moderate power, a great number of stellar clusters and faint nebulous forms are revealed against the dark background of the sky which might be taken at first sight for passing clouds, but which, by their unchanging forms and persistent appearance, are proved to belong to the heavenly bodies, though possessing a character widely differing from the point-like images of ordinary stars. Sir William Herschel was able, with his gigantic forty-foot telescope, to resolve many of these nebulæ into clusters of stars, and found them to consist of vast groups of individual suns, in which thousands of fixed stars may be clearly separated and counted, but which are so far removed from us that we are unable to perceive their distance one from the other, though that may really amount to many millions of miles, and their light, with a low magnifying power, seems to come from a large, faintly-luminous mass. But all nebulæ were not resolvable with this telescope, and, in proportion as such nebulæ were resolved into clusters of stars, new nebulæ appeared which resisted a power of 6,000, and suggested to this astute investigator the theory that, besides the many thousand apparent nebulæ which reveal themselves to us as a complete and separate system of worlds, there are also thousands of real nebulæ in the universe composed of primeval cosmical matter out of which future worlds were to be fashioned.

Lord Rosse, by means of a telescope of fifty-two feet focus, of his own construction, was able to resolve into clusters of stars many of the nebulæ not resolved by Herschel; but there were still revealed to the eye, thus carried farther into space, new nebulæ beyond the power even of this gigantic telescope to resolve.

[1] Abridged from Schellen's "Spectrum Analysis."

Telescopes failed, therefore, to settle the question whether the unresolved nebulæ are portions of the primeval matter out of which the

Fig. 1.

The Great Nebula in Orion.

existing stars have been formed; they leave us in uncertainty as to whether these nebulæ were masses of luminous gas, which in the lapse of ages would pass through the various stages of incandescent liquid

Fig. 2.

South.

North.

Central and Most Brilliant Portion of the Great Nebula in the Sword-handle of Orion, as observed by Sir John Herschel in his Twenty-foot Reflector at Feldhausen, Cape of Good Hope (1834 to 1837).

(the sun and fixed stars), of scoriæ or gradual formation of a cold and non-luminous surface (the earth and planets), and finally of complete gelation and torpidity (the moon), or whether they exist as a complete and separate system of worlds; telescopes have only widened the problem, and have neither simplified nor solved its difficulties.

That which was beyond the power of the most gigantic telescopes has been accomplished by that apparently insignificant, but really delicate, and almost infinitely sensitive instrument—the spectroscope; we are indebted to it for being able to say with certainty that luminous nebulæ actually exist as isolated bodies in space, and that these bodies are luminous masses of gas.

The splendid edifice already planned by Kant in his "Theory of the Heavens" (1755), and erected by Laplace forty-one years later, in his "System of the Univérse," has received its topmost stone through the discoveries of the spectroscope. The spectroscope, in combination with the telescope, affords means for ascertaining even now some of the phases through which the sun and planets have passed in their process of development or transition from masses of luminous nebulæ to their present condition.

Great variety is observed in the forms of the nebulæ: while some are chaotic and irregular, and sometimes highly fantastic, others ex-

Fig. 3.

The Large Magellanic Cloud.

hibit the pure and beautiful forms of a curve, a crescent, a globe, or a circle. A number of the most characteristic of these forms have been photographed on glass at the suggestion of Mr. Huggins; to these have been added a few others, taken from accurate drawings by Lord

Rosse; and they may all be projected on to a screen by means of the electric or lime-light lantern, and made visible to a large audience.

The largest and most irregular of all the nebulæ is that in the constellation of Orion (Figs. 1, 2). It is situated rather below the three stars of second magnitude composing the central part of that magnificent constellation, and is visible to the naked eye. It is extremely difficult to execute even a tolerably correct drawing of this nebula; but it appears, from the various drawings made at different times, that a change is taking place in the form and position of the brightest portions. Fig. 2 represents the central and brightest part of the

Fig. 4.

Nebula of the Form of a Sickle.

nebula. Four bright stars, forming a trapezium, are situated in it, one of which only is visible to the naked eye. The nebula surrounding these stars has a flaky appearance, and is of a greenish-white color; single portions form long curved streaks stretching out in a radiating manner from the middle and bright parts.

Much less irregularity is apparent in the great Magellanic or Cape clouds (Fig. 3), which are two nebulæ in the Southern Hemisphere, one of them exceeding by five times the apparent size of the moon. They are distinctly visible to the naked eye, and are so bright that they serve as marks for reconnoitring the heavens, and for reckoning the hour of the night.

The interest aroused by these irregular and chaotic nebulous forms is still further increased by the phenomena of the spiral or convoluted nebulæ with which the giant telescopes of Lord Rosse and Mr. Bond have made us further acquainted. As a rule, there stream out from

Fig. 5.

Spiral Nebula in Canes Venatici.

one or more centres of luminous matter innumerable curved nebulous streaks, which recede from the centre in a spiral form, and finally lose themselves in space. Fig. 4 represents a nebula in the form of a sickle or comet-tail, and Fig. 5 shows the most remarkable of all the spiral nebulæ, situated in the constellation Canes Venatici.

Fig. 6.

Transition from the Spiral to the Annular Form.

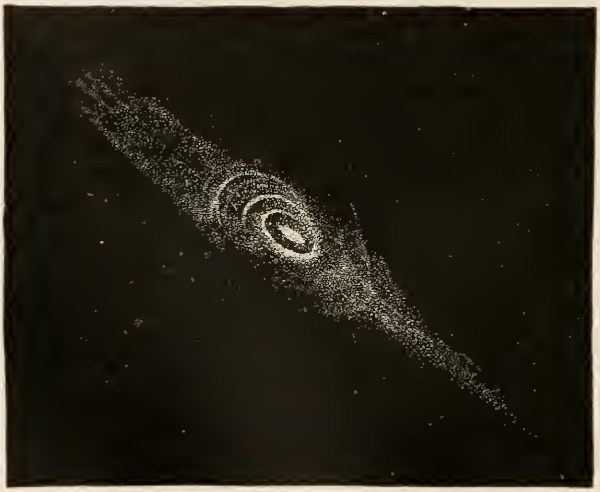
It is hardly conceivable that a system of such a nebulous form could exist without internal motion. The bright nucleus, as well as the streaks curving round it in the same direction, seems to indicate an accumulation of matter toward the centre, with a gradual increase of density, and a rotatory movement. But, if we combine with this motion the supposition of an opposing medium, it is difficult to harmonize such a system with the known laws of statics. Accurate measures are, therefore, of the highest interest for the purpose of showing

Fig. 7.

Annular Nebula in Lyra.

whether actual rotation or other changes are taking place in these nebulæ; but, unfortunately, they are rendered extremely difficult and uncertain by the want of outline, and by the remarkable faintness of these nebulous objects.

Fig. 8.



Nebula with Several Rings.

The transition state from the spiral to the annular form is shown in such nebulæ as the one represented in Fig. 6; and they then pass into the simple or compound annular nebula of a type which is given in Fig. 7.

The space within most of these elliptie rings is not perfectly dark, but is occupied either by a diffused nebulous light, as in Fig. 7, or, as

Fig. 9.

Elliptical Annular Nebula.

in most cases, by a bright nucleus, round which sometimes one ring, sometimes several, are disposed in various forms. In Fig. 8 a representation is given of a compound annular nebula, with very elliptic rings and bright nucleus.

Fig. 10.

Elongated Nebula.

According as the ring has its surface or its edge turned toward us, or according as our line of sight is perpendicular or more or less obliquely inclined to the surface of the ring, its form approaches that of a circle, a ring, an ellipse, or even a straight line. Nebulæ of this latter kind are represented in Fig. 9 and in Fig. 10. When an elliptical ring is extremely elongated, and the minor axis is much smaller than the major one, the density and brightness of the ring diminish as its distance from the central nucleus increases; and this takes place to such a degree sometimes, that at the farthest points of the ring, the ends of the major axis, it ceases to be visible, and the continuity seems to be broken. The nebula has then the appearance of a double nebula, with a central spot as represented in Figs. 11, 12.

Fig. 11.

Double Nebula.

Fig. 12.

Annular Nebula with Centre.

Those nebulæ, which appear with tolerably sharply-defined edges in the form of a circle or slight ellipse, seem to belong to a much higher stage of development. From their resemblance to those planets which shine with a pale or bluish light, they have been called *planetary* nebulæ; in form, however, they vary considerably, some of them being

Fig. 13.

Planetary Nebula with Two Stars.

spiral and some annular. Some of these planetary nebulæ are represented in Figs. 12, 14, 15. The first has two central stars or nuclei, each surrounded by a dark space, beyond which the spiral streaks are disposed; the second has also two nuclei, but without clearly separable dark spaces; the third is without any nucleus, but shows a well-defined ring of light.

The highest type of nebulæ are certainly the stellar nebulæ, in which a tolerably well-defined bright star is surrounded by a completely rounded disk or faint atmosphere of light, which sometimes fades away gradually into space, at other times terminates abruptly with

Fig. 14.

Planetary Annular Nebula with Two Stars.

Fig. 15.

Planetary Nebula.

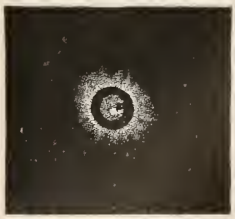
a sharp edge. Figs. 16 and 17 exhibit the most striking of these very remarkable stellar nebulæ: the first is surrounded by a system of rings like Saturn, with the thin edge turned toward us; the second is a veritable star of the eighth magnitude, and is not nebulous, but is surrounded by a bright luminous atmosphere perfectly concentric. To the right of the star is a small dark space, such as often occurs in these nebulæ, indicating, perhaps, an opening in the surrounding atmosphere.

We have now passed in review all that is at present known of the nebulæ, so far as their appearance and form have been revealed by the largest telescopes. The information as yet furnished by the spectroscope on this subject is certainly much less extensive, but is neverthe-

Fig. 16.

Planetary Nebula.

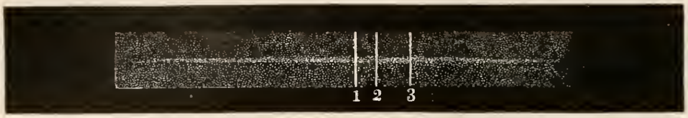
Fig. 17.



Stellar Nebula.

less of the greatest importance, since the spectroscope has power to reveal the nature and constitution of these remote heavenly bodies. It must here again be remembered that the character of the spectrum not only indicates what the substance is that emits the light, but also its physical condition. If the spectrum be a *continuous* one, consisting of rays of every color or degree of refrangibility, then the source of light is either a *solid* or *liquid* incandescent body; if, on the contrary, the spectrum be composed of *bright lines* only, then it is certain that the light comes from *luminous gas;* finally, if the spectrum be continuous, but crossed by *dark* lines interrupting the colors, it is an indication that the source of light is a solid or liquid incandescent body, but that the light has passed through an atmosphere of vapors at a lower temperature, which by their selective absorptive power have abstracted those colored rays which they would have emitted had they been self-luminous.

Fig. 18.

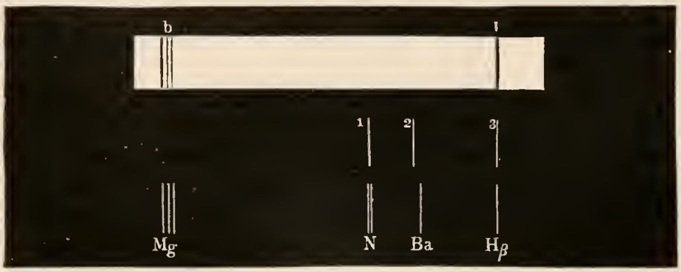


Spectrum of Nebula.[1]

When Huggins first directed his telescope in August, 1864, to one of these objects, a small but very bright nebula, he found, to his great surprise, that the spectrum, instead of being a continuous colored band, such as that given by a star, consisted only of *three bright lines.*

This one observation was sufficient to solve the long-vexed question, at least for this particular nebula, and to prove that it is not a cluster of individual, separable stars, but is actually a gaseous nebula, a body of luminous gas. In fact, such a spectrum could only be pro-

Fig. 19.



Spectrum of Nebula compared with the Sun and some Terrestrial Elements.

duced by a substance in a state of gas; the light of this nebula, therefore, was emitted neither by solid nor liquid incandescent matter, nor by gases in a state of extreme density, as may be the case in the sun and stars, but by luminous gas in a highly-rarefied condition.

In order to discover the chemical nature of this gas, Huggins followed the usual methods of comparison, and tested the spectrum with

[1] From Herschel's Catalogue, No. 4,374.

the Fraunhofer lines of the solar spectrum, and the bright lines of terrestrial elements. A glance at Fig. 19 will show at once the result of this investigation. The brightest line (1) of the nebula coincides exactly with the brightest line (N) of the spectrum of nitrogen, which is a double line. The faintest of the nebular lines (3) also coincides with the bluish-green hydrogen line $H\beta$, or, which is the same thing, with the Fraunhofer line F in the solar spectrum. The middle line (2) of the nebula was not found to coincide with any of the bright lines of the thirty terrestrial elements with which it has been compared; it lies not far from the barium line B*a*, but is not coincident with it.

THE HYGIENE OF THE EAR.

By JAMES HINTON,
AURAL SURGEON TO GUY'S HOSPITAL, LONDON.

IT is natural that we should regard with an intense curiosity all the faculties with which our bodily frame is gifted, and that we should desire to preserve them as perfectly as possible. The following remarks are designed to do something toward gratifying that curiosity with regard to one of the most important of our powers, and to give a few hints in respect to things that are hurtful to it.

Our popular physiologies teach us that there is a tube leading from the drum of the ear into the throat, called, from its discoverer Eustachius, the "Eustachian tube." The use of this tube is twofold. First, it supplies the drum with air, and keeps the membrane exactly balanced, and free to move, with equal air-pressure on each side; and, secondly, it carries off any fluid which may be in the drum, and prevents it from being choked by its own moisture. It is not always open, however, but is opened during the act of swallowing, by a little muscle which is attached to it just as it reaches the throat. Most persons can distinctly feel that this is the case, by gently closing the nose and swallowing; when a distinct sensation is felt in the ears. This sensation is due to a little air being drawn out of the ears through the open tube during swallowing; and it lasts for a few minutes, unless the air is again restored by swallowing with the nose unclosed, which allows for the moment a free communication between the ear and the throat. We thus see a reason for the tube being closed. If it were always open, all the sounds produced in the throat would pass directly into the drum of the ear, and totally confuse us. We should hear every breath, and live in a constant bewilderment of internal sounds. At the same time the closure, being but a light contact of the walls of the tube, easily allows a slight escape of air *from* the drum, and thus not only facilitates and regulates the oscillations of the air before the vibrating membrane, but provides a safety-valve, to a certain extent, against the injurious influence of loud sounds.

The chief use of the Eustachian tube is to allow a free interchange of air between the ear and the throat, and this is exceedingly important; and it is very important also that its use in this respect should be understood. Persons who go down in diving-bells soon begin to feel a great pressure in the ears, and, if the depth is great, the feeling becomes extremely painful. This arises from the fact that in the diving-bell the pressure of the air is very much increased, in order to balance the weight of the water above; and thus it presses with great force upon the membrane of the drum, which, if the Eustachian tube has been kept closed, has only the ordinary uncompressed air on the inner side to sustain it. It is therefore forced inward and put upon the stretch, and might be even broken. Many cases, indeed, have occurred of injury to the ear, producing permanent deafness, from descents in diving-bells, undertaken by persons ignorant of the way in which the ear is made; though the simple precaution of frequent swallowing suffices to ward off all mischief. For, if the Eustachian tube is thus opened, again and again, as the pressure of the outside air increases, the same compressed air that exists outside passes also into the inside of the drum, and the membrane is equally pressed upon from both sides by the air, and so is free from strain. The same precaution is necessary in ascending mountains that are lofty, for then there is the same effect of stretching produced upon the membrane, though in the opposite way. The outside air becoming less and less condensed as a greater height is gained, the ordinary air contained within the drum presses upon the membrane, which is thus insufficiently supported on the outside, and a similar feeling of weight and stretching is produced. The conjurer's trick of breaking a vase by a word rests on the same principle. The air is exhausted from within, and the thin, though massive-looking sides of the vase collapse by the pressure of the air outside; and, just as ever so small a hole, made at the right moment in the side of the vase, would prevent the whole effect, so does swallowing, which makes a little hole, as it were, for the moment in the drum of the ear, prevent the in-pressing or out-pressing of the membrane. Mr. Tyndall, in his interesting book "On Sound," tells us how he employed this precaution of swallowing, and with entire success, when, in one of his mountain excursions, the pressure on his ears became severely painful.

Deafness during colds arises very often, though not always, from a similar cause. For, when, owing to swelling of the throat, the Eustachian tube cannot be opened by its muscle, and so the air in the drum is not renewed, the air that is contained in it soon diminishes, and the outer air presses the membrane in, so that it cannot vibrate as it should. This is what has been sometimes called "throat-deafness."

There are several things very commonly done which are extremely injurious to the ear, and ought to be carefully avoided. Those who have followed the previous description will easily understand the reason.

And first, children's ears ought never to be boxed. We have seen that the passage of the ear is closed by a thin membrane, especially adapted to be influenced by every impulse of the air, and with nothing but the air to support it internally. What, then, can be more likely to injure this membrane than a sudden and forcible compression of the air in front of it? If any one designed to break or overstretch the membrane, he could scarcely devise a more effective means than to bring the hand suddenly and forcibly down upon the passage of the ear, thus driving the air violently before it, with no possibility for its escape but by the membrane giving way. And far too often it does give way, especially if, from any previous disease, it has been weakened. Many children are made deaf by boxes on the ear in this way. Nor is this the only way: if there is one thing which does the nerve of hearing more harm than almost any other, it is a sudden jar or shock. Children and grown persons alike may be entirely deafened by falls or heavy blows upon the head. And boxing the ears produces a similar effect, though more slowly and in less degree. It tends to dull the sensibility of the nerve, even if it does not hurt the membrane. I knew a pitiful case, once, of a poor youth who died from a terrible disease of the ear. He had had a discharge from it since he was a child. Of course his hearing had been dull: and what had happened was that *his father had often boxed his ear for inattention!* Most likely that boxing on the ear, diseased as it was, had much to do with his dying. And this brings me to the second point. Children should never be blamed for being inattentive, until it has been found out whether they are not a little deaf. This is easily done by placing them at a few yards' distance, and trying whether they can understand what is said to them in a rather low tone of voice. Each ear should be tried, while the other is stopped by the finger. I do not say that children are never guilty of inattention, especially to that which they do not particularly wish to hear; but I do say that very many children are blamed and punished for inattention when they really do not hear. And there is nothing at once more cruel and more hurtful to the character of children than to be found fault with for what is really their misfortune. Three things should be remembered here: 1. That slight degrees of deafness, often lasting only for a time, are very common among children, especially during or after colds. 2. That a slight deafness, which does not prevent a person from hearing when he is expecting to be spoken to, will make him very dull to what he is not expecting; and, 3. That there is a kind of deafness in which a person can hear pretty well while listening, but is really very hard of hearing when not listening.

The chief avoidable cause of deafness is catching cold, and whatever keeps us from colds helps us to preserve our hearing. We should do, therefore, those things that help to keep colds away: for which the first is taking plenty of fresh air; the second using enough, but not too much, cold water all over us, taking especial care to rub ourselves thoroughly dry, and never to let it chill us; and the third is to avoid draughts, and wet, especially sitting in wet clothes, or being in close or very heated rooms. But there are some kinds of cold especially hurtful to the ear. One is sitting with the ear exposed to a side wind, as too many people do now on the roofs of omnibuses, and so on. We should always *face* the wind; then, if we are not chilled, it is hard to have too much of it. Another hurtful thing is letting rain or sleet drive into the ear, against which, if it were not that people do sometimes suffer from this cause, it would seem as if it could hardly be necessary to caution them.

Another source of danger to the ear, however, arises from the very precautions which are sometimes taken against those last mentioned. Nothing is more natural than to protect the ear against cold by covering it by a piece of cotton-wool; and this is most useful if it is done only on occasions of special exposure, as when a person is compelled to encounter a driving storm, or has to receive on one side of the head the force of a cutting wind. But it is astonishing in how many cases the cotton-wool thus used, instead of being removed from the ear when the need for it has passed, is pushed down into the passage, and remains there, forming itself an obstruction to hearing, and becoming the cause of other mischiefs. Three separate pieces have sometimes been found thus pushed down, one upon the other. Paper rolled up, which is also used for protecting the ear when cotton-wool is not at hand, is still more irritating when it is thus left unremoved. The way to avoid this accident, besides being careful not to forget, is to use a large piece of wool, and to place it over, rather than in, the passage.

It should be remembered that constantly covering up the ear is adapted to injure it. On the whole, men in whom the ear is habitually exposed, suffer if any thing less from ear-disease than women, in whom it is so often covered. Nor can the "hat" be held an unsafe head-dress in this respect for the latter sex. But it is important that there should not be frequent changes, especially in cold weather, from a head-dress which covers to one which exposes the ear. It is better that the air should always have free access to it; but if this has not been the case, the summer should be chosen to make the change.

All sorts of substances are sometimes put into the ear by children, who do it to themselves or to each other in ignorant play. If every parent and teacher warned his children against doing this, it would not be a useless precaution. When the accident happens, the chief danger is that of undue haste and violence. Such bodies should be removed by syringing with warm water alone, and no attempt should be made to lay hold of them or move them in any other way. It is enough to reflect, again, that the passage of the ear is closed by a delicate membrane to show the reason for this rule. When no severe pain follows, no alarm need be felt. It is important that the substance should be removed as speedily as is quite safe, but there need never be impatience; nor should disappointment be felt if syringing needs to be repeated on many days before it effects its end. It will almost invariably succeed at last in the hands of a medical man, and is most effective if the ear is turned downward and syringed from below.

Now and then an insect gets into the ear and causes great pain; the way to get rid of it is to pour oil into the ear. This suffocates the insect.

There is another danger arising from boyish sports. Snowballs sometimes strike the ear, and the snow remaining in it sets up inflammation. This danger is increased by a practice which should be inadmissible, of mixing small stones with the snow, which thus effect a lodgment in the ear.

Among the causes of injury to the ear must unfortunately be reckoned bathing. Not that this most healthful and important pleasure need, therefore, be in the least discouraged; but it should be wisely regulated. Staying too long in the water certainly tends to produce deafness as well as other evils; and it is a practice against which young persons of both sexes should be carefully on their guard. But, independently of this, swimming and floating are attended with a certain danger from the difficulty of preventing the entrance of water into the ear in those positions. Now, no *cold* fluid should ever enter the ear; cold water is always more or less irritating, and, if used for syringing, rapidly produces extreme giddiness. In the case of warm water its entrance into the ear is less objectionable, but even this is not free from disadvantage. Often the water lodges in the ears and produces an uncomfortable sensation till it is removed: this should always be taken as a sign of danger. That the risk to hearing from unwise bathing is not a fancy, is proved by the fact, well known to lovers of dogs, that those animals, if in the habit of jumping or being thrown into the water, so that their heads are covered, frequently become deaf. A knowledge of the danger is a sufficient guard. To be safe it is only necessary to keep the water from entering the ear. If this cannot be accomplished otherwise, the head may be covered. It should be added, however, that *wet hair*, whether from bathing or washing, may be a cause of deafness, if it be suffered to dry by itself. Whenever wetted, the hair should be wiped till it is fairly dry. Nor ought the practice of moistening the hair with water, to make it curl, to pass without remonstrance. To leave wet hair about the ears is to run great risk of injuring them. In the washing of children, too, care should be taken that all the little folds of the outer ear are carefully and gently dried with a soft towel.

But I come now to what is probably the most frequent way in which the ear is impaired: that is, by the attempt to clean it. It ought to be understood that the passage of the ear does not require cleaning by us. Nature undertakes that task, and, in the healthy state, fulfils it perfectly. Her means for cleansing the ear is *the wax.* Perhaps the reader has never wondered what becomes of the ear-wax. I will tell him. It dries up into thin fine scales, and these peel off, one by one, from the surface of the passage, and fall out imperceptibly, leaving behind them a perfectly clean, smooth surface. In health the passage of the ear is never dirty; but, if we attempt to clean it, we infallibly make it so. Here—by a strange lack of justice, as it would seem, which, however, has no doubt a deep justice at the bottom—the best people, those who love cleanliness, suffer most, and good and careful nurses do a mischief negligent ones avoid. Washing the ear out with soap and water is bad; it keeps the wax moist when it ought to become dry and scaly, increases its quantity unduly, and makes it absorb the dust with which the air always abounds. But the most hurtful thing is introducing the corner of the towel, screwed up, and twisting it round. This does more harm to ears than all other mistakes together. It drives down the wax upon the membrane, much more than it gets it out. Let any one who doubts this make a tube like the passage, especially with the curves which it possesses; let him put a thin membrane at one end, smear its inner surface with a substance like the ear-wax, and then try to get it out so by a towel! But this plan does much more mischief than merely pressing down the wax. It irritates the passage, and makes it cast off small flakes of skin, which dry up, and become extremely hard, and these also are pressed down upon the membrane. Often it is not only deafness which ensues, but pain and inflammation, and then matter is formed which the hard mass prevents from escaping, and the membrane becomes diseased, and worse may follow. *The ear should never be cleaned out with the screwed-up corner of a towel.* Washing should extend only to the outer surface, as far as the finger can reach.

Ear-picks, again, are bad. If there is any desire to use them, it shows that the ear is unhealthy; and it wants soothing, not picking. And there is another danger from introducing any solid thing into the ear. The hand may get a push, and it may go too far. Many is the membrane that has thus been broken by a bodkin. Sportsmen sometimes have their membrane pierced by turning suddenly while getting through a hedge. And it even happens that a boy at school may put a pen close to another's ear, in play, and call to him to make him turn his head; and the pen pierces the membrane. Very loud sounds may cause deafness, too. Artillerymen, and also eager sportsmen, and very zealous volunteers, incur a danger from this cause. It is well to stop the ears when exposed to loud sounds, if possible; also to avoid belfries when the bells are about to ring. A man who was once shut up in one became stone-deaf before the peal was done. The sound of guns is more injurious to those who are in a confined space with them, and also if the mouth be open. Injury from loud sounds, also, is much more likely to occur if they are unexpected; for, if they are anticipated, the membrane is prepared for them, without our knowledge, by its muscles. At certain points on the Rhine, it is, or was, the custom of the captain of the steamboat to fire a small cannon, to exhibit the echo. When this has been done without due warning, it has proved more than once a cause of lasting deafness. Sometimes these loud sounds rupture the membrane; sometimes they deaden the nerve: the former is the least evil.

It is a bad practice, also, to put cotton-wool soaked in laudanum or chloroform into the ear for the relief of toothache. It may be sometimes effectual, for the nervous connection between the teeth and the ear is very close. But the ear is far too delicate and valuable an organ to be used as a medium for the application of strong remedies for disorders of other and less important parts; and laudanum, and more especially chloroform, is a powerful irritant. The teeth should be looked after in and for themselves, and, if toothache spreads to the ear, that is the more reason for taking them thoroughly in hand; for prolonged pain in the head, arising from the teeth, may itself injure the hearing. When a child's ear becomes painful, as it so often does, every thing should be done to soothe it, and all strong, irritating applications should be avoided. Pieces of hot fig or onion should not be put in; but warm flannels should be applied, with poppy-fomentation, if the pain does not soon subside. How much children suffer from their ears, unpitied because unknown, it would probably wring the hearts of those who love them suddenly to discover. It is often very hard, even for medical men, to ascertain that the cause of a young child's distress is seated in the ear, and frequently a sudden discharge from it, with a cessation of pain, first reveals the secret of a mysterious attack which has really been an inflammation of the drum. The watchfulness of a parent, however, would probably suffice to detect the cause of suffering, *if directed to this point*, as well as to others. If children cry habitually when their ears are washed, that should not be neglected; there is, most likely, some cause of pain. Many membranes are destroyed from discharges which take place during "teething." Whenever there is a discharge of matter from the ear, it would be right to pour in warm water night and morning, and so at least to try and to keep it clean. But into the treatment of diseases of the ear it would not be suitable to enter here.—*Abridged from the People's Magazine.*

ECONOMY OF RAILWAY LOCOMOTION.

By J. W. GROVER, C. E.

THE primary conception of a railway is a perfectly smooth, level, and straight road, upon which friction is reduced to the minimum, so that heavy loads may be propelled with the least possible resistance, and at the highest rate of speed.

The earliest type of locomotive-engine was designed to run upon such straight and level roads, and it was supposed for many years that locomotives could not climb hills, or be made to go round corners.

The first railway-carriages were a simple modification of the stage-coaches, names and all. It is interesting to look at the curious three-bodied "Marquis of Stafford"—with yellow panels and windows, filled with ladies in large coal-scuttle bonnets—as shown in one of Ackermann's early engravings of the Liverpool and Manchester Railway, the only substantial difference being that, inasmuch as the railways of those days were made nearly straight, no arrangement was provided for allowing the axles of the carriage to radiate as they do partially in common road-vehicles, but both axles were rigidly fastened so as to be immovable.

Again, as all road-vehicles have to turn abrupt corners, their wheels are made to turn independently upon their axles, but, so soon as flanges were employed to keep the wheels of the railway-carriages between two straight rails, this arrangement was found unnecessary, and, to obtain greater strength and security, the wheels were rigidly fastened to the axle, and both were compelled to revolve together.

Now, since the primary conception of the perfectly smooth, straight road, a great degeneracy has been of necessity taking place; with greatly increased demands, less capital than ever has been forthcoming; consequently the great cuttings and embankments of early days are being abandoned as precedents, and it becomes necessary that railways should approach more closely to the form of ordinary roads, which follow the surface of the ground only, at small cost.

Hence it follows that the rolling-stock itself must revert more nearly to its original pattern, readopting those contrivances which, under altered circumstances, were discarded.

Let us keep to the most elementary principles, for it is these which are forgotten and misunderstood, and yet should be engraven on brass and hung up in every railway board-room in the world. On a common road, a horse can pull a ton weight in a cart behind him on the level at 4 to 4½ miles an hour, or, which is the same thing, if a weight of 70 lbs. were hung over a pulley and lowered down a well, he could pull it up at the speed mentioned. It is necessary to be a little explicit, as the remarks in this paper are intended for non-technical readers particularly. Now, if two strips of iron called rails are laid upon the aforesaid road, the friction is reduced sevenfold; that is to say, the same horse at the same speed could draw 7 tons, the difference between macadam and iron being as 70 lbs. to 10 lbs. This immense advantage, however, disappears when gradients have to be encountered, because the resistance due to gravity becomes so greatly in excess of the resistance due to friction, and is constant in both cases. For instance, if on a common road, up a slope of one foot in ten, the horse takes 5 cwt. in a cart over the macadam, if rails be laid down up the same hill, he could only increase the burden behind him by a little more than 1 cwt., or, in all, 6¼ cwts.; hence, in this case, the value of the rails is nearly lost. Hence the small use of tramways where hills occur.

Upon a very good macadamized road the resistance due to friction is usually taken at about *one-thirtieth* of the whole load carried; that is to say, if the vehicle were put upon a road sloping 1 in 30, it would just begin to move of itself. But, upon a railway, under the most favorable conditions, the resistance due to friction has been reduced to the *two-hundred-and-eightieth* part of the whole load carried; that is to say, the vehicle will begin to move of itself on a gradient of 1 in 280. In considering the work which a horse can perform on a tramway, it is important to bear in mind the question of speed; for, according to the experiments of Tredgold, he can draw exactly four times as much at two miles an hour as he can at five, and it appears that, at three miles an hour, he does the greatest amount of actual useful work, whereas, at ten miles an hour, only one-fourth of his actual power is available, and he cannot exert that for an hour and a half; whereas, at two and a half miles an hour, he can continue working for eight hours. Having these data before us, it is easy to compare the values of steam and horse-flesh: Suppose coals to cost in the midland districts 18*s*. 8*d*. a ton only, or one-tenth of a penny per pound, and, assuming that an average locomotive-engine will not consume more than 5 lbs. of coal in the hour per horse-power, the cost of fuel per horse-power will be a halfpenny per hour. Taking the value of the horse's provender at 1*s*. 9*d*. a day only, and supposing he works for six hours, that would cost 3½*d*. an hour against a halfpenny in the case of steam, or, as 7 to 1 in favor of steam; and this result is obtained on the supposition that the horse travels only at three miles an hour.

Now, to sum up the combined advantages, therefore, of an engine on a level railway against a horse on a level common road at 10 miles an hour, we shall find that the former gives an economy over the latter of nearly 300 to 1; at 5 miles an hour, it would stand as 115 to 1; and, at 2½ miles an hour, as 64 to 1.

Such are the enormous advantages of *steam and rails*, and with them does it not seem astonishing that better financial results have not been obtained? There must be something wrong somewhere. As Artemus Ward says, "Why is this thus, and what is the reason of this thusness?"

Speed is the delinquent, and the cause of the loss of the great primary advantages: the vehicles on railways are propelled very fast; hence they involve great strength in their construction, and enormous weight in proportion to the paying load carried.

An old stage-coach, according to Nicholas Wood, weighed only 16 to 18 cwts., and would carry upward of 2 tons of paying passengers with their luggage, or about $\frac{4}{10}$ of a hundred-weight of dead load to every hundred-weight of paying load. Now, a third-class carriage with four compartments would represent 2.8 cwts. of dead weight to every 1 cwt. of paying load. Therefore, the stage-coach has the advantage over the third-class railway-carriage of $6\frac{1}{2}$ to 1.

It becomes impossible to institute any absolute comparison between roads and railways at speeds above 10 miles an hour, because such speeds are impossible on the former for any considerable distance. Again, the question of a gradient has to be noticed, for in the preceding remarks a level road and a level railway have only been considered.

As has been explained, where steep gradients occur, the resistance due to gravity so much outweighs that due to friction that rails afford a comparatively insignificant advantage, and one which is entirely lost if the stock has to be increased in weight $6\frac{1}{2}$ times.

It may easily be shown that, on a gradient of 1 in 10, for instance, taking the foregoing figures, the advantages of a steam-worked railway over a horse-worked road would be little more than one-fourth, if the stock on the former be only $6\frac{1}{2}$ times heavier in proportion than the latter would require. Hence it follows that no railway having gradients of 1 in 10 could be worth making (assuming such to be possible) unless the stock upon it were assimilated to that of the ordinary omnibus or stage-coach type.

In former times calculations were made by Nicholas Wood of the comparative costs of conveyance on ordinary roads by horses; he showed that on an average a stage-wagon could carry at the rate of $2\frac{1}{2}$ miles an hour profitably at 8*d.* a ton per mile; that a light van or cart at 4 miles an hour could take for 1*s.* a mile a ton of goods. Passengers in stage-coaches were charged 3*d.* a mile each, or 3*s.* 6*d.* a ton, at 9 miles an hour. Now, let us consider what railways actually do. At the present moment coals are conveyed at $\frac{5}{8}$*d.* per ton per mile, at an average speed of 20 miles an hour; and this low rate actually leaves a profit. Excursion-trains take passengers at less than $\frac{1}{2}$*d.* each per mile, at twenty miles an hour, or at 7*d.* a ton a mile.

Now, bearing in mind the relative proportions of paying and non-paying loads involved in carrying passengers and coals, a simple calculation will show that a ton of passengers could be carried for something less than 1*d.* a mile, or $\frac{1}{14}$ part of a penny each. For, although passengers require station accommodation, they unload themselves, which coals do not.

In the autumn of 1869, the *Times* took up the railway problem, and, in a series of very able articles, endeavored to show the errors of the present state of things. Although advocated by so powerful a pen, the reforms still remain unaccomplished—indeed, uncommenced. It was then shown that in practice every passenger on a railway involved over 2 tons—of iron and timber—to carry him. Or, according to Mr. Haughton, no more than 30 per cent. of the load which is hauled by a goods-train represents paying weight, the remaining 70 per cent. being dead weight. This seems astonishing truly, but it is nothing to the passenger-trains, where only 5 per cent., or even less, of the load pays, the remaining 95 per cent. being made up of apparently dead and unprofitable material. It is well to keep this clearly in view. In talking about a passenger, with relation to a railway, one must not picture to one's self a respectable English country gentleman, riding perhaps some 14 stone, but some Homeric giant, magnified into prehistoric proportions, weightier than an ordinary Ceylonese elephant, and representing about 20 to 25 full sacks of coal, or $2\frac{1}{4}$ tons.—*Abstract from Quarterly Journal of Science.*

INSTINCT IN INSECTS.

BY GEORGE POUCHET.

TRANSLATED BY A. R. MACDONOUGH, ESQ.

II.

LET us now dwell a little on two grand facts presented to us by the animated world, these two properties of living beings equally undeniable and unintelligible in their essence—habit, and hereditary tendency; and let us see how, in Darwin's theory, they will combine with intelligence. As the theory is well known, we need not state it. Cuvier believed in the unchangeableness of the animal forms placed on the globe by the Creator after each of the great convulsions through which, as he held, our planet has passed. Modern geology questions these violent commotions, and Darwin, taking up in his turn Lamarck's ideas, after fifty years of scientific progress, maintains, by almost irresistible arguments, that animal forms, instead of being unchangeable, as Cuvier supposed, are slowly modified, under the control of time, of circumstances, and of the energies with which each individual and each race "fight the battle of existence." That individual which brings into life a slight yet advantageous modification of its organs will succeed better in life than another. It will have every chance, then, of leaving a more numerous posterity. If the advantageous modification is transmitted, which may occur through hereditary tendency, the descendants of this individual will have, in their turn, the chance of succeeding better than their contemporaries. The modification, then, in all probability, will go on becoming more general, by the same law of fatality that causes a strong people to absorb a weak one: so that, after a longer or shorter time, the whole race will end by presenting the modification which was only individual at the outset. And since there was no reason why the same phenomenon, so natural and so simple, should not be repeated indefinitely, with all imaginable variations, we understand how it may result, in the infinite lapse of time, in that multiplicity of forms and characters which distinguishes animal species to our eyes.

Darwin says, in those pages in which he treats of instinct, that, if it were possible to prove that a habit might become hereditary, all distinction between habit and instinct would absolutely vanish. Darwin's literary procedure is that of always urging his reader further than he seems to go himself. He suggests the best arguments in the world with a doubtful air, and one is every moment surprised to find one's self so strongly convinced when the author seems convinced so little. And, in fact, we cannot deny that young puppies often come to a point the very first time they are sent out hunting, and that even better than others after long training. The habit of saving life is hereditary in some breeds, just as the shepherd's dog has the habit of walking around the flock. All these acts are performed, without the aid of experience, by the young as well as the old, and certainly apart from any notion of the object—at the first time, at least. The objection is idle that only those habits imposed by men on brutes are transmitted in this way. More than one instance, taken from wild animals, proves the contrary. The best is perhaps that which we see done by a bird of our own country, the oriole. It has a very peculiar cradle-shaped nest, hung from the fork of a branch, sewed at the edges with flexible grass, and always with bits of string, shreds, or packthread. There is no oriole's nest without some fastening worked by man's hand. If this is a habit, it is hereditary; if it is an instinct, it will be admitted at least that it does not go back to the beginning of the world.

From birth, one individual, or several individuals of the same species, placed in similar conditions, have had some habit. One of two things: this habit is injurious, or it is useful; it is either good or bad, from the point of view of the preservation of the individual, and consequently of the species. If it is injurious, it necessarily tends to disappear, either with the individual which has taken it on, or with the descendants which will inherit from it. If the habit is favorable, it has the chance of transmitting itself under the form of an instinct. This instinct, at first confined to a few individuals of the same blood, tends to become general, since it is advantageous, and we thus fall back into a particular case of the great principle of natural selection formulated by Darwin. Let us go on. Thus far this instinct is but little complicated, since it has only the significance of a habit that one individual may have been able to take up with its share of intelligence. Now that it is seen rooted under the form of instinct, each individual in its turn, with its own share of intelligence, may be able to add something to it of its own accord. If that addition is still favorable, and again gets transmitted, it will tend in the same way to become general; the acquired instinct will grow so much the more complex; and, exactly as organic modifications scarcely perceptible, but accumulated successively, to a sufficient number, have been able to multiply animal forms infinitely, so instinct, by almost imperceptible but continuous additions, may be able to end by reaching that state of perfection in which philosophers had supposed they saw the convincing proof of a preëstablished harmony.

Some naturalists even now are not, very fortunately, inspired when they attempt to prove to us that the corporeal organization of every animal is conceived and framed with regard to its instincts. We need not go far to learn, as indeed we might expect from what has gone before, that instinct is in many cases independent of external forms. All birds, whether they are masons, like the swallow; weavers, like the warbler; carpenters, like the crow; mound-builders, like the *mégapode*—have the same beak, the same claws, and forms almost the same. The European beaver, inhabiting the affluents of the Rhone and the Danube, is scarcely to be distinguished from the American beaver, yet he has quite a different kind of work to do. The American beaver, on his lakes and great, lonely rivers, builds the famous houses so well known; the European beaver burrows long galleries underground in the manner of moles. If he has always done so, what becomes of that supposed necessary correlation between the organs and the instinct of a burrowing animal on one continent, a building animal on the other, with the same members for two objects so different? If the European beaver did once build huts, where shall we find more decisive testimony in favor of the theory of mutability in instincts? Pursued for his warm covering and his flesh, he has changed his instincts, before invading civilization, more rapidly than his external form. It is a point well established at this day that the contact with man has had a decisive effect on the instinct of many animals. It is thus that in inhabited countries large birds take flight at his approach, while they still allow him to come close to them in countries visited by travellers for the first time. Wherever they have been hunted like a prey that is worth the trouble of pursuit for their flesh or their feathers, they have formed the habit, and then have had the instinct of taking flight.

Let us return to insects. Two instincts, the most remarkable among all, are presented by them; that of the bee, with its mathematical architecture, and that of the ant, with its mixed societies. Before inquiring whether it might not be possible to explain even such amazing instincts by habit and inherited tendency, it is important at the outset to remove an objection that might be supposed unanswerable. Those individuals that have these instincts in the hive or in the ant-hill are neuters—that is to say, they are neither male nor female, and must consequently die without posterity. How explain the way in which a habit acquired by a neuter can be transmitted, can grow into an instinct, in the neuters of following generations, which will not descend from that first one? Yet the difficulty is not so great as it seems, and Darwin points it out very well. Indeed, it is not the instincts of the neuters which concern him, but it is the special organic modifications that these present, in connection with their social duties—with some, labor, and with others, fighting; but the reasoning he employs can be applied as well to instincts, behind which there always appears, as we see by a little reflection, that latent modification of the cerebral organ through which the transmission has taken place.

Darwin begins with a reminder that the principle of natural selection is true as well for communities as for individuals. The strength of a single male in a wild herd, the extraordinary fecundity of a single female, will be the elements of prosperity. The herd will succeed better than the rest. The qualities of the individual from which it draws its advantage will have a chance of being transmitted at first to all the herd, and this, more and more favored in the struggle against the outer world, will absorb the rest. The modification, at first individual, will become general. It would be the same if the member of the herd benefited in the beginning had been a neuter. We are still speaking of external forms. Let us suppose that a certain number of neuters may have brought from birth a favorable organic modification into a community of insects, and that by this the community has prospered; the males and females who have produced these neuters will then have, by them, the greatest possible chances of posterity. It may happen thenceforward that they transmit to their descendants what they had themselves—that is to say, the property of procreating neuters having the same favorable organic modification—and we thus fall back into the common process of natural selection. Such is Darwin's explanation; he is well aware, when he gives it, complex as it is, that it is the touchstone of his theory, the side whence attack will come; therefore, how he strengthens his arguments! He is no longer satisfied with explaining, he demonstrates; he is supposed to have exhausted his reasons, and this is the very moment he chooses for an appeal to experiment, and to the proof of that kind of paradox that might be called "hereditary tendency in sterility." There are oxen with horns a little longer than those of the bulls and heifers that produced them. "Well," says Darwin, "pair together, by attentive selection, the fertile descendants of the bulls and heifers that produced the oxen with longer horns, and before long you will have a race of oxen in which length of horns will be hereditary, although the animal is sterile." The experiment has yet to be made, and is worthy of being a temptation to some one of the great English lords who know so well how to spend their fortunes for the advance of science. There is every reason to believe that it would succeed; and, if this striking instance ever comes, to justify Darwin's theories in their points most difficult of explanation, how can we avoid accepting them in their completeness, as well for external forms as for instinct?

Neuters in a community bring at their birth an intellectual disposition, a special tendency. The community benefits by it, and prospers; but the parents of these neuters have produced, besides, males and females, who will be able to inherit in their turn the property of giving life to neuters having the same disposition or the same tendency with the first. This becomes hereditary; it fixes itself in the race; it is thenceforward an instinct; and it will be able to continue developing itself thus by a sort of collateral inheritance. The source of it will continue in the parents without its being necessary that they should have it themselves, exactly as the reason for the long horns of the oxen is in the parent bull and heifer which have only short ones themselves.

Even after confuting this great objection of the neuters, the problem of explaining the architecture of bees by natural conditions seemed still to defy every attempt. Yet Darwin undertook to solve it. Aided by the experiments of his countryman Waterhouse, he shows that all this labor, worthy of the most practised geometrician, can be reduced, in the last analysis, to a certain number of very simple habits, taken in succession, so that by a linking together of facts, hypothetical, it is true, yet all perfectly plausible and possible, we arrive at the discovery, in the biological laws already known, of a natural explanation of that instinct which seems to share in the miraculous. We know the subject in question. The cells of the bee are six-sided prisms of perfect regularity. The most interesting point is the bottom of the cell; it is formed of a hollow pyramid of three equal sides, and arranged in such a manner that each contributes its share, on the other side of the comb, to make the bottom of a distinct cell; the bottom of each cell thus rests on three cells on the other side of the comb. Buffon did not remark this combination; he only spoke of the regular hexagonal design of the whole, and on this subject he had a singular idea. "The bees," he said, "all want to make a cylindrical chamber for themselves in the wax, but room is wanting; on the comb, which is too small, each one attempts to settle itself in the way most convenient for itself, at the same time that all are equally in each other's way. The cells are hexagonal only on account of reciprocal obstacles. For the same reason," he adds, "as, if we fill a vessel with peas or cylindrical grains, shut it tightly after pouring in as much water as the intervals between these grains can receive, and set the water boiling, all these cylinders will become six-sided columns." Buffon's comparison has been a good deal laughed at, yet it is not altogether bad. He understood that each cell with its sides cut at regular angles was not an individual work, nor the direct execution of the original plan; that it was a kind of resultant brought about by the forced neighborhood, the mutual crowding and hindering of constructions conceived on a simpler plan, and one more usual among insects, the cylindrical chamber.

The humble-bees, which are hymenopterous insects, like honey-bees, put their store of honey away in their old cocoons. When the vessel is too small, they add to it at the opening a prolongation of wax. It may even occur that they build single cells, of an irregular globular form; this is a first step, the primitive wax-working. There is nothing very remarkable yet in this; but the next step becomes more important. Between this rude simplicity and the work, so finished, of the bee, we find something intermediate, the honey-cells of the domestic *mélipone*, of Mexico. The insect itself forms a transition, by its external marks, between the honey-bee and the humble-bee, and is nearer to the latter. To preserve its honey, it builds a pile of large spherical cells, all placed at equal distances apart, only that this distance is everywhere less than twice the radius of the spheres, so that they all encroach on each other, and are kept apart by a perfectly flat partition, having exactly the same thickness as the curved wall that bounds the free and spherical portion of each cell. If three are found to adjoin, the lines of separation cross at equal angles, and their common meeting-point rests on the top of a pyramid with three walls formed by the three cells, exactly as in a honeycomb. Reflecting on all this, Darwin says the thought occurred to him that, if the mélipone, which already builds its spheres at equal distances apart, were to come to disposing them symmetrically and back to back upon two opposite sides, there would result from this fact a construction as admirable as the bottom of a double rank of cells in the hive.

Has the constructive genius of the wasp and the bee passed through these transitions? It is impossible to assert it; but the evidence shows, and calculation confirms it, that some modifications, slight enough definitely, occurring in the instincts of the mélipone, might lead it, after an indefinite number of ages—we must always calculate on such periods of time—to build those three-angled pyramids which are already found in its constructions, in two or three ranks; then to build upon those pyramids, on each side, prolongations cylindrical in principle, like those which the humble-bee puts on its cocoons, and prism-shaped from their nearness to each other. Besides, such a construction upon a flat surface of its honey-cells by the mélipone would be nothing very extraordinary; in this way it builds the little chambers where it deposits its grubs.

In the general effort that produces the honey-comb, it is important to make allowance for that supreme law of necessity which Buffon refers to, and which compels each insect, if it makes a mistake in its measurements, to begin its work again, under penalty of seeing it destroyed by its neighbors. The bee's cell is no more an individual work than it is a work finished all at once. At the beginning, the six-sided plan is scarcely indicated; the original wall is clumsy, oftentimes too thick; it is attempted a second time, made thinner at the bottom, thickened at the top, crowded by force into its right place, and worked over and over constantly to the last perfection. The geometric regularity of the whole is the result of long tentative work. A multitude of bees are laboring on it at once, each for a time at one cell, then at another, and so on; twenty insects at least busy themselves with the first chamber, which at the outset is very irregular; new chambers are added, and the first remade. On all these points Darwin and other English naturalists have made very curious experiments, which deserve to be cited along with the observations of Francis Huber. He observed, to learn; they experimented, to explain. By dealing with swarms or individuals properly isolated, by modifying their conditions of labor, by deceiving their instinct, we should doubtless succeed in decomposing it by a kind of physiological analysis, at the same time that we should ascertain more clearly the tolerably large share that intelligence probably has in this industry of the bee. This is an aspect of the problem that is perhaps too much neglected by Darwin, but indicated by Mdlle. Clémence Royer in the notes added by her to the French translation of the "Origin of Species." We may ask, Why should not the bee itself be sensitive to that harmony of lines which strikes our eye in its work? Why deny so simple an impression as that which springs from regularity, to that brain which is of tiny dimensions, it is true, but which is quick to seize relations of far greater complexity between cause and effect, quick to choose the best place, to avoid an obstacle, to pursue with eye and sting the enemy of the hive? We have seen how the ant understands when an object is too large to pass through the entrance to its cave. The bee, to which we would attribute sensitiveness to regularity of lines, certainly has the notion of relations of length. There is a large moth, the death's-head sphinx, very fond of honey, and which asks nothing better than to make its way into the hive; its body, hairy and covered with horny plates, defies the sting. The bees, dreading this unwelcome visit, know very well how to protect themselves from it in regions where the sphinx abounds. As soon as the earliest ones begin to show themselves in the evenings of the longest days, as M. Blanchard relates, the bees narrow the opening of the hive in such a way that the robber can no longer get in. When the season for this moth has gone by, they destroy the new construction, and rebuild the passage of its original size. Certainly these are creatures that have a measuring eye! Is there, then, so wide a distance between this power of eye and the sense of symmetry, which the lowest savage has who is sensitive to the harmony in the lines of a carving or a tattooing? Is it not simpler to suppose that the bee has something of the same sensibility, rather than a sort of mathematical instinct, such as is sometimes attributed to it? The whole cerebral physiology of insects remains to be created. While we are no further advanced, it is perhaps rash to allow much to their intellectual faculties, but it is certainly unreasonable to degrade them too much. And, besides, there is still in us that old sin of pride, on which Montaigne rallies us so delicately, just with respect to the reason of animals. He understood animals much better than Descartes; he loves them, he plays with his cat, and this intercourse enlightens him; he speaks with sound judgment of the too narrow share of intelligence allowed to animals by man, while he himself "goes soaring in imagination beyond the orbit of the moon."

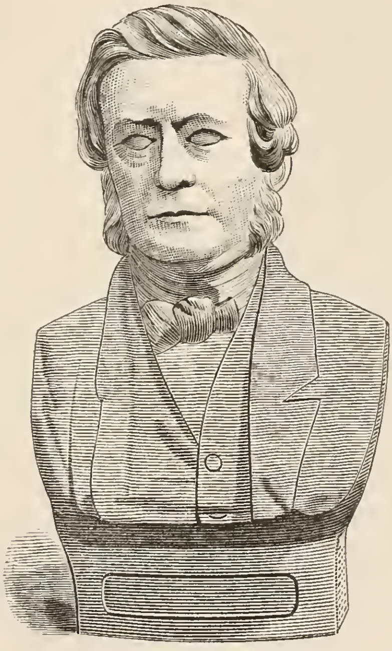
As to the legionary ants, the connection of the successive phenomena serving to explain the appearance and development of their instinct was far more difficult to conceive. We might well have despaired of any reasonable deduction, had not certain facts, here and there in Nature, come to our aid and put us on the right track, by showing us elsewhere the same instinct, less developed, or modified in different ways. These observations, coördinated by Darwin, have been like flashes of light, and have allowed us to conceive the evolution of these singular habits in a manner at least plausible. Thus, it is not uncommon that certain ants, which do not usually take auxiliaries, carry away to their hills nymphæ that are found by chance in their neighborhood. It is not unlikely that some of these nymphæ may have happened to come out, and may have performed the functions of their special instinct in their adopted city. If, now, it is admitted that these services may be of some use to the hill, then it will thrive better, and afterward it may happen that the same chance captives and chance comings-out of nymphæ may be repeated. At last, the habit will be formed—then the instinct will supervene, of carrying off stolen nymphæ. At the same time the presence of these strangers will almost necessarily react upon the robber-ants. Their instincts and their organs will be simultaneously modified, always upon the same principle, in the direction most favorable to the special duty that they perform in the community. From step to step, by a succession of scarcely-perceptible modifications, accumulating through centuries and ages, we shall arrive at races of legionaries as dependent on their comrades' labors as the species studied by Peter Huber.

Each instinct that we study displays itself to us, in a manner, under an absolute form; we never see it change; therefore it is said to be unchangeable. This is the illusion common to all phenomena that are too slow for their progress to be measured by the life or the memory of man. Yet the European beaver and the oriole give us examples of instincts that go back to a date relatively not very ancient. We know now, too, that the nests of the same species of birds sometimes present remarkable enough variations in different countries. That Darwin should point out with great care these instincts, varying with latitudes, is very natural; but we should less naturally expect to find a similar fact, in the book of a partisan, of the unchangeableness of instincts. The leaf-cutter, another hymenopterous insect, lays its eggs in little chambers made of bits of leaves which it has rapidly cut. In our country it is always a rose-leaf. Yet, "we are assured," says M. Blanchard, "that our cutter of rose-leaves, finding itself in some place in Russia where there are no rose-bushes, makes its nest with willow or osier leaves." Therefore, instinct must vary in space as it has varied in time! It is not at all the case that the same legionaries are everywhere as dependent on their comrades as those that Peter Huber saw in the environs of Geneva. In England, as in Switzerland, the auxiliaries reared by the dark-red ants take complete care of the larvæ, while the legionaries alone go on expeditions; but in Switzerland the two castes together busy themselves about all works of construction or supply, while in England the legionaries alone go out to gather provisions and materials; the auxiliaries remain shut up within; they thus render less service to the community than they do in Switzerland.

It will be said, perhaps, that these differences are a very trifling matter. They are, at least, enough to show how the ancient doctrine of Cuvier has been shaken, and how, in the infinite lapse of time, those instincts may have become developed, which mere geographical accidents suffice to modify slightly. The grand solution of instinct is —Time; that immeasurable duration of those geological epochs which our mind holds in contemplation, but of which it can no more form an idea than of the measure of the heavenly spaces. Modern science begins to be amazed at those figures of ages which it must count since the rude attempts at primitive human industry. What shall we think of those times, measured by the planet's growth, through which the instinct of the legionary ants may have been originated, defined, and perfected? The ant not only saw the epoch of the reindeer and the mammoth, and the glaciers of the Jura creeping down the valley of the Rhone—it was a contemporary of that period which geologists mark by the lifting of the Alps. The ant is older on the earth than Mont Blanc. They existed already in the Jurassic period, very little different from what they are in our own times. While an inland sea still flowed over the site where later Paris was to stand, they were multitudinous in the central regions of Europe that were out of water. We may judge of this by the mass of their remains; they fill thick layers of territory at Oeningen, on the shores of Lake Constance, and at Radoboj, in Croatia; the rock is black with ants, all wonderfully preserved, with their claws and delicate antennæ. Entomologists now count fifty species in Europe. More than a hundred have been found by Heer, of Zurich, and Mayr, of Vienna, in the cantons of Oeningen and Radoboj alone; several seem identical with existing species. Most of them have wings; these are males and females. Workers are rare; and that is explained by the nature of the rock, deposited at the bottom of still waters. The winged insects fell into it by thousands; the workers, more lowly in existence, attached to earth, have left fewer victims in the streams that preserve the record of that age. For the same reason, those sepulchres, so rich in species, teach us nothing of the habits or abodes of the ants of that time. What we do know is, that there were also plant-lice in the country, and that the larvæ of *phryganes* made for themselves even then, as they do now, those cases in which they live, and which they carry about everywhere with them. Some of these have been found at Oeningen. We have butterflies' wings of that era with their marks, if not with their coloring. Who knows whether we shall not some day discover a wasps'-nest dropped from a bough, and a trifle less regular than those of to-day? Even were it just as perfect, that would in nowise weaken the hypothesis of progressive development in the instinct by which it was built. Should we not have, beyond the Jurassic epoch, an enormous past, beside which the actual age now of the deposits of Oeningen and Radoboj is, perhaps, like a day or an hour in the history of man?

The grand result which the introduction of Darwin's ideas into biological science has had is, beyond question, to have transformed a subject hitherto deemed unapproachable and insolvable into a question of development that may be attacked by our investigations. Instinct, like the outward forms of animals, has always been made dependent on those first causes too high for man to raise his look to them. The observations of the English naturalist have brought the problem upon new ground; his logic, his science, have forced the world to accept at last the ideas formerly defended by Cuvier's opponents, by Lamarck and Geoffroy Saint-Hilaire. The doctrine of the immutability of animal forms has had its time, and that of the invariability of instinct is falling into ruin. Darwin proves, in fact, that it suffices to admit the principle of intelligence, which no one now denies to animals, and then the twofold influence of habit and hereditary tendency, and last that law, stated by himself, of absorption of the poorly-endowed races by those better endowed, to reach the conclusion that the finely-perfected instinct of the bee or the ant is nothing more than a purely natural phenomenon, a necessary consequence of life. The most complex instinct is merely an hereditary accumulation of very simple habits, of which the first source was always in the spontaneous intelligence of the individual. Instinct, then, including that of neuter animals, may be defined, "a group of habits, slowly acquired, and fixed by inheritance." Then it appears to us as independent, in some degree, of the forms of the animal; the variations it presents find their explanation;

it is contingent, it originates, it is modified, through circumstances, aided by time, and through ages helped by scarcely-perceptible accidents. In its turn, it insensibly leads the organs to become perfect in the direction conformed to the use made of them by the animal. Regarded in this way, connected in the last analysis with other first properties from which it results, instinct, instead of baffling investigation by the human mind, as they do, becomes a possible and proper object of research by experimental science. It is a new horizon opening before the physiologist for the discovery of the laws of life.—*Revue des Deux Mondes.*



Professor Henslow.

A SCIENTIFIC HOME MISSIONARY.[1]

JOHN STEPHENS HENSLOW is described as having been a beautiful boy with brown curling hair, a fine straight nose, a brilliant complexion, soft eyes, and a smile that reached everybody's

[1] The subject of the present sketch, who became an eminent clergyman, botanical professor, and scientific philanthropist, was born in Kent, England, in 1796. For the principal facts of the present article we are indebted to his biography by Rev. Leonard Jenyns, Henslow's brother-in-law, published by Van Voorst, of London, and we have made free use of his statements.—Ed.

heart. He was active, observant, and intelligent, a favorite partner at childish parties, and danced elegantly. This beautiful boyhood unfolded into a noble manhood, which took a turn so original and instructive, that we cannot do better than give some account of it to the readers of the POPULAR SCIENCE MONTHLY.

Young Henslow early developed a taste for the study of natural objects, and for making collections and experiments. His scientific future was symbolized by an adventure made while yet a child in a frock, and which consisted in dragging all the way home from a field, a considerable distance off, an enormous fungus which was dried and long preserved in the family. The lad had good blood and a good chance; his grandfather, Sir John Henslow, Chief Surveyor of the Navy, was a man of scientific attainments and much ingenuity; his mother was an accomplished woman, fond of natural history, and an assiduous collector of natural and artificial curiosities. His father had a great taste for birds, kept an extensive aviary, and had an ample library of natural history. The drawing-master at his school was a good entomologist and introduced the boy to some of the eminent naturalists of the day, who gave direction to his studies. He collected insects in the woods of Kent, and crustacea and shells from the bed of the Medway. many of his specimens were new and valuable, and found their way into the drawers of the British Museum. At the age of eighteen he entered St. John's College, Cambridge, and four years later took his degree of B. A. A year subsequently, in 1819, he accompanied Prof. Sedgwick to the Isle of Wight, where he took his first practical lessons in geology. He had been elected Fellow of the Linnæan Society in 1818, became a Fellow of the Geological Society in 1819, and made his first essay in authorship by a contribution to its proceedings in 1821, when twenty-five years of age. Mr. Henslow had paid much attention to mathematics in college, was a thorough student of mineralogy and chemistry, and took a leading part in founding the Cambridge Philosophical Society, in 1819. In 1822 he was elected Professor of Mineralogy in the Cambridge University. He was not an eloquent lecturer, but he had a good voice, and a remarkably clear way of expressing himself. He cultivated the art of explanation and adapting his language to the capacity of his hearers, and thus became one of the very best lecturers of the day. But the chair of Mineralogy was not what Prof. Henslow wanted. His favorite study was botany, and, a vacancy occurring in this professorship, Prof. Henslow was elected to the position in 1823. This science, and natural history generally, were in a low state in the university at that time.[1] His predecessor

[1] "In a low state," the reader must remember, not merely from neglect, but from hostility on the part of the classicists and mathematicians who had possession of the establishment. Even years afterward, when, mainly under Prof. Henslow's influence, natural history studies began to receive attention, Edward Forbes spent a couple of days in Cambridge and wrote: "I was greatly pleased with my visit, except in one thing—to

had held the professorship for sixty-three years, and was a very old man. In fact, there had been no lectures on botany given in Cambridge for at least thirty years. Prof. Henslow took hold of the work with great zeal, improved the Botanical Gardens, rearranged and extended the Botanical Museum, and established one of the most perfect collections of plants to be anywhere found. He made his lectures extremely interesting by always having large numbers of specimens on hand which the students were required to study directly. He often took his class on botanizing excursions, which tended greatly to rouse their interest in the subject. Entomologists and mineralogists often accompanied them, and Prof. Henslow's extensive acquaintance with all branches of natural history, and the delight he took in imparting information to all who sought it, served to kindle an enthusiasm which aided very much to raise the position of science in the university.

Prof. Henslow married in 1823. His parents had always been desirous that he should go into the Church, and, as the salary from his professorship was less than a thousand dollars a year, and insufficient to support his family, he took orders and accepted a curacy which yielded him some additional income. His engaging manners and sympathetic disposition, combined with his intellectual accomplishments, gave him great influence over the students, which was felt not only in directing their tastes and pursuits, but in the formation of character. As soon as he became settled in Cambridge as a married man, he instituted the practice of receiving at his own house, one evening in the week, all who took the slightest interest in scientific, and especially natural history studies. At these gatherings all might learn something, and every one went away pleased. He would seek out any of the students that were reported to him as attached to natural history, and made converts to his favorite science of not a few who were thrown accidentally in his way. If any young man through timidity or reserve shrank from going to the professor's house, the open-hearted welcome which he received soon inspired confidence and put him at his ease. There are many now among the first naturalists of England who were then students at Cambridge, and who gratefully acknowledge the encouragement and assistance they received from Prof. Henslow, and bear testimony to his rare excellences, both of head and heart. Among these is the now world-renowned naturalist Mr. Charles Darwin, who furnished to Prof. Henslow's biographer the following reminiscences, which will interest the reader as well on account of the writer as of their subject. Mr. Darwin says:

find that natural history is discouraged as much as possible, and regarded as idle trifling by the thousand-and-one mathematicians of that venerated university." It was a life-long struggle of Prof. Henslow to raise natural history to a coördinate place with other subjects of university study, and it was but a short time before his death, in 1861, that he saw the triumph of his efforts. Degrees were then first granted to those who had obtained "honors" in natural history studies.

"I went to Cambridge early in the year 1828, and soon became acquainted, through some of my brother entomologists, with Prof. Henslow, for all who cared for any branch of natural history were equally encouraged by him. Nothing could be more simple, cordial, and unpretending, than the encouragement which he afforded to all young naturalists. I soon became intimate with him, for he had a remarkable power of making the young feel completely at ease with him; though we were all awe-struck with the amount of his knowledge. Before I saw him, I heard one young man sum up his attainments by simply saying that he knew every thing. When I reflect how immediately we felt at perfect ease with a man older and in every way so immensely our superior, I think it was as much owing to the transparent sincerity of his character, as to his kindness of heart; and, perhaps, even still more to a highly-remarkable absence in him of all self-consciousness. One perceived at once that he never thought of his own varied knowledge or clear intellect, but solely on the subject in hand. Another charm, which must have struck every one, was that his manner to old and distinguished persons and to the youngest student was exactly the same: to all he showed the same winning courtesy. He would receive with interest the most trifling observation in any branch of natural history; and, however absurd a blunder one might make, he pointed it out so clearly and kindly, that one left him no way disheartened, but only determined to be more accurate the next time. In short, no man could be better formed to win the entire confidence of the young, and to encourage them in their pursuits.

"His lectures on botany were universally popular, and as clear as daylight. So popular were they, that several of the older members of the university attended successive courses. Once every week he kept open house in the evening, and all who had cared for natural history attended these parties, which, by thus favoring intercommunication, did the same good in Cambridge, in a very pleasant manner, as the scientific societies do in London. At these parties many of the most distinguished members of the university occasionally attended; and, when only a few were present, I have listened to the great men of those days, conversing on all sorts of subjects, with the most varied and brilliant powers. This was no small advantage to some of the younger men, as it stimulated their mental activity and ambition. Two or three times in each session he took excursions with his botanical class; either a long walk to the habitat of some rare plant, or in a barge down the river to the fens, or in coaches to some more distant place, as to Gamlingay, to see the wild-lily of the valley, and to catch on the heath the rare natter-jack. These excursions have left a delightful impression on my mind. He was, on such occasions, in as good spirits as a boy, and laughed as heartily as a boy at the misadventures of those who chased the splendid swallow-tail butterflies across the broken and treacherous fens. He used to pause every now and then, and lecture on some plant or other object; and something he could tell us on every insect, shell, or fossil collected, for he had attended to every branch of natural history. After our day's work we used to dine at some inn or house, and most jovial we then were. I believe all who joined these excursions will agree with me that they have left an enduring impression of delight on our minds.

"As time passed on at Cambridge, I became very intimate with Prof. Henslow, and his kindness was unbounded. He continually asked me to his house, and allowed me to accompany him in his walks. He talked on all subjects, including his deep sense of religion, and was entirely open. I owe more than I can express to this excellent man. His kindness was steady. When Captain

Fitzroy offered to give up part of his own cabin to any naturalist who would join in the expedition in H. M. S. Beagle, Prof. Henslow recommended me as one who knew very little, but who, he thought, would work. I was strongly attached to natural history, and this attachment I owed, in large part, to him. During the five years' voyage, he regularly corresponded with me, and guided my efforts. He received, opened, and took care of all the specimens sent home in many large boxes; but I firmly believe that, during these five years, it never once crossed his mind that he was acting toward me with unusual and generous kindness.

"During the years when I associated so much with Prof. Henslow, I never once saw his temper even ruffled. He never took an ill-natured view of any one's character, though very far from blind to the foibles of others. It always struck me that his mind could not be even touched by any paltry feeling of vanity, envy, or jealousy. With all this equability of temper and remarkable benevolence, there was no insipidity of character. A man must have been blind not to have perceived that beneath this placid exterior there was a vigorous and determined will. When principle came into play, no power on earth could have turned him one hair's-breadth.

"After the year 1842, when I left London, I saw Prof. Henslow only at long intervals; but, to the last, he continued in all respects the same man. I think he cared somewhat less about science, and more for his parishioners. When speaking of his allotments, his parish children, and plans of amusing and instructing them, he would always kindle up with interest and enjoyment. I remember one trifling fact which seemed to me highly characteristic of the man: In one of the bad years for the potato, I asked him how his crop had fared, but, after a little talk, I perceived that, in fact, he knew nothing about his own pototoes, but seemed to know exactly what sort of crop there was in the garden of almost every poor man in his parish.

"In intellect, as far as I could judge, accurate powers of observation, sound sense, and cautious judgment, seemed predominant. Nothing seemed to give him so much enjoyment as drawing conclusions from minute observations. But his admirable memoir on the geology of Anglesea shows his capacity for extended observations and broad views. Reflecting over his character with gratitude and reverence, his moral attributes rise, as they should do in the highest character, in preëminence over his intellect. C. DARWIN."

The moral heroism, here testified to by Mr. Darwin, was an eminent trait of Prof. Henslow's character, and a key to his career; but there was one instance of it, in Cambridge, which may be mentioned in passing. In politics, Prof. Henslow was originally a Conservative or Tory. Lord Palmerston had long represented the university on the same side. But when the Duke of Wellington, who was at the head of the government, declared against reform in any shape whatever, there came a revolution which overthrew his administration, and Lord Palmerston went over to the Liberal side and joined the reformed ministry. Prof. Henslow, like many others, fell in with the movement, and, of course, made himself obnoxious to the charge of being a "turn-coat." He did not flinch from these attacks, and was at any moment ready to do his duty regardless of popular reprobation, and he soon had an opportunity of incurring it. In the borough election of 1835, the "Tory agents" had notoriously resorted to bribery. The Liberals wanted to bring the offenders into court, but no one would incur the odium of "informing" against them. Under these circumstances Prof. Henslow readily offered himself as the nominal prosecutor. The storm of abuse and persecution that broke upon him for this is still well remembered in Cambridge. His biographer remarks: "Not only was the cry raised of 'Henslow, common informer!' whenever he appeared in the streets, but the same obnoxious words were placarded upon the walls in such large and enduring characters, that, even to this day (1861), more than a quarter of a century after the transaction, they are still distinctly legible in some places. They were seen, and smilingly pointed out to a friend, by the professor himself, within a year of his death, and I have, since his death, seen and read them myself. His services were, however, deeply appreciated at the time, for he received three handsome testimonials: one from the town of Cambridge; another from the town committee for the suppression of corruption; and the third from a committee of noblemen and gentlemen." The rule that Prof. Henslow laid down for the guidance of conduct in such circumstances, and which he rigorously conformed to himself, was expressed in the following noble words: "I would have every Tory consistent, and every Radical consistent, and every Whig consistent, until either of them shall have become convinced that he has been in error, and then I would have him change his politics, regardless of every risk, and despising the shame which the world will heap upon him. But what I would have every man strive to possess is 'moral courage,' sufficient to declare his own opinions unhesitatingly in the face of the world, and adequate to maintain them unflinchingly against all influence whatever."

The position of Prof. Henslow at Cambridge was every thing that would satisfy the usual ambition of a man of science. He was profoundly appreciated in the institution, he was beloved by the students, and he had given a new life to the class of studies to which he was devoted. Yet all this did not satisfy him, and he seized the first opportunity to leave Cambridge, and enter a field of labor of a very different kind, and for which, as the result proved, he was remarkably endowed. As his talents and high character became known, the Government sought his influence for some of the responsible trusts in its gift, and it was in contemplation to offer him the See of Norwich. It is a terrible temptation in England to get the place of bishop, and while many sigh, labor, and intrigue for it, those who decline it when offered are exceedingly few. Prof. Henslow, when he heard of the danger, fled to his chamber, and prayed fervently to be delivered from the temptation. His prayers were answered, and, instead of the bishopric, he received the crown living of the parish of Hitcham, with an income of a thousand pounds a year. The place is in Suffolk, not far from Cambridge, and he entered upon the charge of it in 1837. His first intention was to continue his relation with the university, and divide his work between Cambridge and Hitcham; but, finding that the duties of the latter place did not permit his absence, he took up his residence there in 1839. How different was the sphere of exertion upon which he had now entered will be apparent when we glance at the condition of the inhabitants of the parish when he first went among them.

The village of Hitcham consisted of one long, straggling street, and the parish contained rather more than a thousand persons, scattered over some 4,000 acres of land. The property of the parish was assessed at $30,000 a year, yet there was only a dame-school in the place. The unemployed and vagabond laborers were so numerous that the poor-rate in 1834 amounted to $5,000—equal, it was said, to over $6 for each man, woman, and child, in the village. The people were sunk to almost the lowest depths of moral and physical debasement. Ignorance, crime, and vice were rife, and the worst characters were addicted to poaching, sheep-stealing, drunkenness, and all kinds of immorality. The less vicious were more fond of idleness than work, and lolled about the road-sides, dead to all sense of moral shame, so long as they could live at the parish expense. Parish relief or charity was .not unfrequently levied by bands of forty or fifty able-bodied laborers who had been in the habit of intimidating the previous rector into instant compliance with their demands. The houses of the poor were described as having been many of them little better than hovels, in which the common decencies of life could hardly be carried out. The church was almost empty on Sunday, and but little respect was paid to its ordinances. The previous rector had been satisfied with discharging his usual Sunday duties, and left the people to themselves during the week.

Such was the field which Prof. Henslow left Cambridge to cultivate. He went there as a missionary, to reclaim it from inveterate heathenism, which still passed under a Christian name. His difficulties were of the most formidable kind, and he had to grapple with them single-handed, for there were no influential persons in the parish either to coöperate in his work, or to encourage him in pursuing it. The parties with whom he had to deal were the farmers who rented the land from the landlords, and the laborers whom the farmers employed. The farmers are represented as having been intellectually raised but little above their laborers, as ignorant, obstinate, and prejudiced, and they doggedly opposed the new rector in all his schemes, and threw every possible obstacle in his way. But he was not a man to flinch from what he had undertaken, and, coolly estimating the difficulties of the situation, he set himself to work to reclaim his flock from their degradation, to industry, sobriety, independence, and self-respect. It was obvious enough that the inculcation of moral and religious lessons would have been utterly lost upon them—would have been like throwing pearls before swine—because men must be civilized before they can be effectually Christianized. Prof. Henslow therefore commenced by gaining the confidence of those whom he wished to influence, and to do this he had to adapt himself to them, and utilize whatever forces he could find available. He began by amusing them. He got up a cricket club, and encouraged various manly games. He introduced ploughing-matches, and competitive exhibitions. His acquaintance with chemistry enabled him to construct fireworks, which he would let off upon the rectory lawn, and which were a great attraction to the people. He brought out various natural and artificial curiosities, which were at first vacantly stared at, but, with his extraordinary faculty of adapting his language and illustrations to the commonest capacity, he gradually kindled an interest in the minds of many which grew into a desire to learn. Other recreations and incitements followed, which will be presently referred to. Prof. Henslow resorted to many measures of amelioration and improvement, and carried them all along together; but, in our brief sketch of his labors, we must consider them separately; and we will take up first what he did for the laborers, next for the farmers, and lastly, what he accomplished for the education of the children:

One of the first evils which he attacked was the degradation and dependence of the laborers. The Hitcham farmers held their men in brutal subjection, viewing them as little better than slaves, for whose concern they felt no interest. They were, therefore, the enemies of every measure for the improvement of the laboring-class. Prof. Henslow considered the lack of an independent home as one of the great barriers to the elevation of the working-men, and he therefore urged the adoption of the "allotment system," by which the laborers might become the owners or tenants of small pieces of ground, to be cultivated by themselves for their own benefit. This encountered the fiercest opposition from the farmers, and led to a long and determined struggle. All sorts of objections were raised. It was said the laborers would steal the farmers' seed to sow their own ground; they would give their masters slack work in order to reserve their strength for their own patches at the end of the day. But the worst difficulty was the profound class or caste spirit which pervades English society, and which impelled the farmers to fight the change, because it would raise the laborer, and bring him one step nearer to themselves. It was in 1845 that Prof. Henslow made his first public appeal upon this subject, in which he pointed out the many advantages that would result from the allotment system to the laboring-class. He urged the reform energetically, and initiated it by granting portions of his own land for the purpose. He pushed the project until he had got fifty more of one-quarter of an acre each. The farmers here made a stand, and determined to crush the whole system. They went into coöperation, and gave mutual pledges that they would "refuse all employment and show no favor to any day-laborer who should hold an allotment."

The storm raged about the rector, who persevered without losing either his patience or his temper. He denounced the selfish action of the farmers, and gave them to understand that he would submit to no dictation, and was determined to carry out his intentions. Fortunately, his salary and position did not depend upon them, as they would quickly have dismissed him; but, finding that the rector's purpose was not to be shaken, their opposition at length abated. The measure was extended, and the most salutary consequences followed in the general conduct of the people. Many instances were known in which "an allotment has been the means of reclaiming the criminal, reforming the dissolute, and of changing the whole moral character and conduct." At the time of Prof. Henslow's death the allotments in his parish amounted to nearly 150 in number, and their advantages were no longer denied.

Nor did Prof. Henslow encounter much less difficulty in his efforts to improve the condition of the farmers themselves. A good chemist, botanist, and geologist, and a close student of scientific agriculture, he was prepared to help the agriculturists with applied and available knowledge, yet they strenuously resisted his efforts to teach them. But he was not to be baffled in his exertions. He took up the practical subject of the economy of fertilizers, in a series of popular letters to a country newspaper, and treated it with such familiarity and skill as to arrest the attention of the farmers. He spoke to them in the farmers' club upon the same subject, and the address, together with the letters, was printed and widely distributed. Having at length aroused their attention, he pressed them into the work of testing the proposed views, by observations and experiments of their own. The relative value of different kinds of organic and inorganic manures, their adaptation to special crops, how they should be applied, and the extent to which manure-heaps should be allowed to ferment and decompose, were open questions, and he showed the farmers that they were the parties to settle them. Liebig had suggested the addition of gypsum to the manure-heap, to fix the ammonia, and Henslow suggested that the farmers of Suffolk should try the experiment; and, to get as many enlisted as possible, he circulated printed forms to be filled up by the experimenters with the results to which they might arrive. But few at first responded to the call, and all kinds of objections were urged; but at length 69 farmers sent in applications for the printed forms, and consented to undertake the experiments. The result of these efforts was the stirring up of the farmers to a more methodical and scientific way of conducting their agricultural operations. Prof. Henslow did not expect to make them philosophers, but to make them think, and to do something toward converting the art of husbandry into the science of agriculture; and he received many communications which showed that his letters and lectures had exerted a wide and wholesome influence.

It was in connection with these efforts to aid the farmers that Prof. Henslow made the memorable discovery of the agricultural value of the so-called coprolites, or phosphatic nodules, found in the red crag at Felixstowe, in Suffolk. They were shown to contain 56 per cent. of phosphate of lime, and therefore to be capable of replacing bones in fertilization. He called attention to the similar concretions abundantly distributed in the upper greensand of Cambridgeshire, which were even richer in phosphate, and which have since yielded immense profits both to the proprietors of the pits and the farmers who used the product.

Prof. Henslow had paid much attention to entomology; and his knowledge of plants, and the parasitic insects which infest them and destroy the crops, enabled him to instruct the farmers upon this subject. He closely investigated the diseases of wheat, potatoes, and clover, and diffused the results of his inquiries in lectures, tracts, and newspaper correspondence.

As he lived in an agricultural community, in which all were interested in farm products and processes, Prof. Henslow resorted to other means of quickening the general interest in these matters, and of enlisting the sympathy of laborers as well as farmers. For this purpose he instituted horticultural shows, at which there was a distribution of prizes for such products as wheat, fruit, flowers, vegetables, and honey, and sometimes for works of mechanical ingenuity calculated to encourage the laborers to spend their long winter evenings profitably. There were two of these shows in each season, in July and September. They began in 1850, and were kept up until the time of his death. Tents were pitched for receiving the productions of the cottagers' gardens, and the allotment-tenants received premiums for the best management of their pieces of ground. Besides the tents for the more special purposes of the show, there was always one assigned to a miscellaneous collection of specimens in natural history—animals, birds, reptiles, insects' nests, etc., with various specimens from the domestic arts and antiquities. This the professor called his "Marquee Museum." On one occasion the dimensions of the trunk of the great mammoth tree (*Wellingtonia*) were traced out on the lawn with a diagram, showing its size in comparison with other trees. There was much to gratify the eye; but sight-seeing is always wearisome, and Prof. Henslow alleviated the routine of the day, and gave an intellectual turn to the proceedings, by summoning as many of the company as chose to come to the museum, and delivering to them little lectures, or "lecturets," as he termed them. He would talk to the women about textile fabrics or domestic operations, and to the different groups on processes of manufacture, or local specimens of natural history, or the diseases of vegetation. Nor were amusements neglected; swings and poles were set up for gymnastic exercises, and foot-ball and other games were encouraged on the grounds. The scene was one of entertainment and instruction, and promotive of good feeling on the part of all who participated in it. The influence of these exhibitions was so beneficial, and became so well known, that large numbers flocked to them from a distance, and similar shows were got up in other places.

One of the schemes devised by Prof. Henslow for alleviating the hard, monotonous life of the laboring population, and combining recreation with improvement, was the arrangement of excursions to neighboring places of interest. Knowing that those who always stay at home are apt to become narrow and prejudiced, he sought to afford them the opportunity of observing the ways and habits of other places, and to open to them not merely agreeable sights, but sources of knowledge from which they had been previously shut out. From one to two hundred persons usually accompanied him, and his preparations for these excursions were always very methodical; for he aimed to combine moral discipline with healthful amusement. A "recreation fund" was raised, and the poor always contributed something toward the expenses. Tickets were issued, limiting the number of those attending, and printed circulars were sometimes prepared with plans of the route, regulations for the party, and often copious notes concerning the place and objects to be visited. An eleven-page pocket-guide was got up on one occasion for the use of the visitors at Cambridge, giving an account of the colleges, museums, and libraries of the university. Sometimes they went to the neighboring towns, to manufacturing places, or to the sea-shore. But the professor was always ready with his interesting "lecturets" to explain every thing to his flock of eager listeners. The impression left by these holiday excursions upon the minds and hearts of the simple laborers was most gratifying, and, as one of them remarked to Prof. Henslow, "Our heads would not be so full of drink if we had such things to occupy our minds."

The task which Prof. Henslow had undertaken was one of immediate and practical social amelioration, and this compelled him to grapple with the adult ignorance and the indurated prejudices of the community. But he did not forget the children. When he went to Hitcham, there was but a single, very poor school in the parish, but he lost no time in establishing a better one. Meeting with but little support from his parishioners, he had to bear the greater part of the expense himself in the erection of a school-house and the payment of a teacher. He had to deal with the children of an ignorant and stolid peasantry, yet he brought his scientific resources to bear upon them with such success that his humble parish-school acquired a national reputation, was visited by people from all parts of the country, and was inquired into by Parliament when settling the policy of its public schools.

Prof. Henslow struck boldly out from the traditional method, and did a thing unheard of in England, which was, to introduce his favorite science of botany into a school for the children of the lowest classes. Prof. Henslow's object was to break in upon the slavish and stupefying routine of the schoolroom, and to substitute, for the endless drudgery of mere lesson-learning from books, the exercise of the childish faculties upon Nature itself. His object was to awaken the mind to spontaneous action, to open the observant faculties, and expand the reasoning powers, rather than to impart second-hand knowledge, and to load the memory with the contents of books. And this he succeeded in doing. He introduced a study which excited their interest, and "furnished them with innocent and rational amusement in those leisure hours which so many servants and poor idly throw away when their required work is done;" which "tends to raise their thoughts to the contemplation of the Creator, and to make them mindful as well as observant of that infinite wisdom and goodness of which they see everywhere around them such abundant proofs," and which, moreover, taught them the use of their minds in inquiring, comparing, judging, and thinking for themselves.

It is to be observed that Prof. Henslow did not, by any means, undertake to establish a botanical school; in fact, but a very small portion of the time was given to the subject. His habit was to attend the school regularly every Monday afternoon, for the purpose of giving a lesson in botany from an hour and a half to two hours in length, the main work of the pupils being by themselves and out of school. The pupils varied in age from eight to eighteen, and the class was limited to 42 in number. Into the details of his teaching we have no space here to enter. The whole essence and value of it consisted in the regular and constant study of plants themselves. The pupils ranged the woods and fields of Hitcham for specimens, and their work consisted in dissecting, analyzing, and classifying them. The class was graded; the older pupils became teachers, and the younger were promoted as they became proficient in their work. The children made herbariums of dried plants, and one pupil-teacher "actually collected in rural strolls, and afterward dried and correctly named, more than 250 specimens of plants." The children brought their botanical acquirements to bear to enrich the horticultural show, to which reference has been made. They brought their dried collections and fresh, wild-flower nosegays, and competed for the prizes offered for the largest collections, the most tasteful arrangements, and the most accurate descriptions. In 1858, at the July show, 50 children competed for the "wild-flower nosegay," and 26 received prizes.

It is almost superfluous to say that this invaluable experiment in education was not an example of "compulsory education." Compulsion implies resistance; a resort to brute force, when higher forces fail, or are not tried. But the coercive system forces the question upon us, Is anybody fit to teach who cannot wield the higher agencies of control? Should not the very first qualification of a teacher of the young be a love of children? This, at all events, was a prime qualification of Prof. Henslow. His biographer says: "He had a playful way with children, which won their affections, as well as their attention to what he was teaching them, and which was one secret of their success. He would always speak kindly to them, and encourage them in their different little ways. All who competed for the wild-flower nosegay prizes, though they did not succeed in getting a prize, were allowed a pinch of 'white snuff,' as he jokingly called it, or sugar-plums. He generally had a snuffbox full of these sugar-plums in his pocket when he went into the village, offering a pinch to any of the little children whom he happened to meet." Of course, his botanical pupils were all volunteers. They entered with spirit into their work, took it home with them, pursued it in their rambles, recurred to it in hours of play, compared notes among themselves, and needed no "compulsion." How eager was their delight, was shown by their grief whenever the lessons were interrupted. In a public address, Prof. Henslow said: "No one who had heard the lamentations uttered upon my announcing, at our last lesson before Easter, the necessity of six weeks' absence at Cambridge duties, could possibly have doubted the great interest the children took in these exercises."

As to the educational value of this teaching, although it occupied but a small fraction of regular school-time, it was of the highest importance. It was not merely that the children got a knowledge of botany, but that they mastered its rudiments in such a way as to gain the most important intellectual benefits. There is plenty of unmistakable evidence upon this point; we have space only for an extract from the cautious statement of one of her Majesty's inspectors of schools, who says: "That the botanical lessons, as handled by the professor in his own national school, did draw largely upon the intelligent powers of his little pupils' minds, there can be no question. The simple system to which he had reduced his plan of making the children break up the various specimens into their component parts, arrange those parts, observe their characters and relations to each other, and thence *arrive at conclusions for themselves*, was very far from being the mechanical process which many, before witnessing it, might have supposed 'botany in the national schools' to represent. And I think it is not at all unfair to say that these children, who, out of school, were (as I had many opportunities of judging) much more conversable than the generality of children in rural parishes, owed a considerable share of the general development of their minds to the botanical lessons and the self-exercise connected with them."

Prof. Henslow's method of teaching botany to the young was one of his great successes, and is a permanent contribution to education. He commenced a little book embodying the plan, but did not live to finish it; and he got along with printed lists, forms, and schedules, all being directed by his lectures and by his constant supervision of the plant-studies of his pupils. The fame of his success went abroad, and he was solicited to lecture in many places, and to assist in organizing the botanical work in various schools and colleges. Like Faraday, he was invited by Prince Albert to lecture to the royal children, whom he interested in the same way that he had done the pupils of his Hitcham classes.

Other points of great interest in Prof. Henslow's career and character we should be glad to dwell upon, but our sketch is already overdone. Sufficient, however, has been said to show how science may increase the usefulness of a clergyman, and prepare the way for his higher work—and that higher work was not neglected by Prof. Henslow. He not only labored hard and perseveringly for the temporal good of his parishioners, but he discharged toward them with fidelity the duties of a Christian minister. In the twenty-four years of his residence at Hitcham there was a period of twelve years when he was not absent from the parish on a single Sunday. The secret of so much varied work was a strong constitution, unremitting industry, and strict method in the disposal of his time. But the strongest constitutions have their limits, and a false security tends to their being often overpassed. Prof. Henslow was under a constant strain, and the illness that terminated his life was probably brought on by his "incessant mental and manual labor." He passed away May 14, 1861, and his loss was deeply felt in the world of science, in his university, and in the parish to which he had devoted so much of his unselfish life.

THE STUDY OF SOCIOLOGY.

By HERBERT SPENCER.

XI.—*The Political Bias.*

EVERY day brings events which, showing the politician what the events of the next day are likely to be, serve also as materials for the student of Social Science. Passing occurrences may have their special meanings sought, as by the many, or may have their general meanings sought, as by the few. Scarcely a journal can be read, that does not supply a fact which, beyond the proximate implication seized by the party-tactician, has an ultimate implication of value to the sociologist. Thus *à propos* of political bias, I am, while writing, furnished by an Irish paper with an extreme instance. Speaking of the late Ministerial defeat, the *Nation* says:

"Mr. Gladstone and his administration are hurled from power, and the iniquitous attempt to sow broadcast the seed of irreligion and infidelity in Ireland has recoiled with the impact of a thunder-bolt upon its authors. The men who so long beguiled the ear of Ireland with specious promises, who mocked us with sham reforms and insulted us with barren concessions, who traded on the grievances of this country only to aggravate them, and who, with smooth professions on their lips, trampled out the last traces of liberty in the land, are to-day a beaten and outcast party."

Which exhibition of feeling we may either consider specially, as showing how the "Nationalists" are likely to behave in the immediate future; or may consider more generally, as giving us a trait of Irish nature tending to justify Mr. Froude's harsh verdict on Irish conduct in the past; or may consider most generally, after the manner here appropriate, as a striking example of the distortions which the political bias works in men's judgments.

When we remember that all are thus affected more or less, in estimating political antagonists, their acts and their views, we are reminded what an immense obstacle political partisanship is in the way of Social Science. I do not mean simply that, as all know, it often determines opinions about pending questions; as shown by cases in which a measure, reprobated by Conservatives when brought forward by Liberals, is approved when brought forward by their own party. I refer to the far wider effect it has on men's interpretations of the past and of the future; and therefore on their sociological conceptions in general. The political sympathies and antipathies fostered by the conflicts of parties, respectively upholding this or that kind of institution, become sympathies and antipathies drawn out toward the allied institutions of other nations, extinct or surviving. These sympathies and antipathies inevitably cause tendencies to accept or reject favorable or unfavorable evidence respecting such institutions. The well-known contrast between the pictures which the Tory Mitford and the Radical Grote have given of the Athenian democracy, serves as an instance to which many parallels may be found. In proof of the perverting effects of the political bias, I cannot do better than quote some sentences from Mr. Froude's lecture on "The Scientific Method applied to History:"

"Thucydides wrote to expose the vices of democracy; Tacitus, the historian of the Cæsars, to exhibit the hatefulness of imperialism."[1]

"Read Macaulay on the condition of the English poor before the last century or two, and you wonder how they lived at all. Read Cobbett, and I may even say Hallam, and you wonder how they endure the contrast between their past prosperity and their present misery."[2]

"An Irish Catholic prelate once told me that to his certain knowledge two millions of men, women, and children had died in the great famine of 1846. I asked him if he was not including those who had emigrated. He repeated that over and above the emigration two millions had actually died; and added, 'we might assert that every one of these deaths lay at the door of the English Government.' I mentioned this to a distinguished lawyer in Dublin, a Protestant.

[1] Froude, "Short Studies on Great Subjects," Second Series, 1871, p. 480.

[2] Ibid., p. 483.

His gray eyes lighted up. He replied: 'Did he say two millions now—did he? Why, there were not a thousand died—there were not five hundred.' The true number, so far as can be gathered from a comparison of the census of 1841 with the census of 1851, from the emigration returns, which were carefully made, and from an allowance for the natural rate of increase, was about two hundred thousand." [1]

Further insistance on this point is needless. That the verdicts which will be given by different party journals upon each ministerial act may be predicted, and that the opposite opinions uttered by speakers and applauded by meetings concerning the same measure may be foreseen if the political bias is known, are facts from which any one may infer that the party politician must have his feelings greatly moderated before he can interpret, with even approximate truth, the events of the past, and draw correct inferences respecting the future.

Here, instead of dilating upon this truth, I propose to draw attention to kindred truths that are less conspicuous. Beyond those kinds of political bias indicated by the names of political parties, there are certain kinds of political bias transcending party limits. Already in the chapter on "Subjective Difficulties—Emotional," I have commented upon the feeling which originates them—the feeling drawn out toward the governing agency. In addition to what was there said about the general effects of this feeling on sociological speculation, something must be said about its special effects. And first, let us contemplate a common fallacy in men's opinions about human affairs, which pervades the several fallacies fostered by the political bias.

Results are proportionate to appliances—see here the tacit assumption underlying many errors in the conduct of life, private and public. In private life every one discovers the untruth of this assumption, and yet continues to act as though he had not discovered its untruth. Reconsider a moment, under this fresh aspect, a familiar experience lately dwelt upon.

"How happy I shall be," thinks the child, "when I am as old as my big brother, and own all the many things he will not let me have!" "How happy," the big brother thinks, "shall I be when, like my father, I have got a house of my own and can do as I like!" "How happy I shall be," thinks the father, "when, achieving the success in prospect, I have got a large income, a country-house, carriages, horses, and a higher social position!" And yet at each stage the possession of the much-desired aids to satisfaction does not bring all the happiness expected, and brings many annoyances.

A good example of the fallacy, that results are proportionate to appliances, is furnished by domestic service. It is an inference naturally drawn that, if one servant does so much, two servants will do twice as much; and so on. But when this common-sense theory is tested by

[1] Froude, "Short Studies on Great Subjects," Second Series, 1871, pp. 483, 484.

practice, the results are quite at variance with it. Not simply does the amount of service performed fail to increase in proportion to the number of servants, but frequently it decreases: fewer servants do more work and do it better.

Take, again, the relation of books to knowledge. The natural assumption is, that one who has stores of information at hand will become well informed. And yet, very generally, when a man begins to accumulate books he ceases to make much use of them. The filling of his shelves with volumes, and the filling of his brain with facts, are processes apt to go on with inverse rapidities. It is a trite remark that those who have become distinguished for their learning have often been those who had great difficulties in getting books. Here, too, the results are quite out of proportion to the appliances.

Similarly, if we go a step further in the same direction—not thinking of books as aids to information, but thinking of information as an aid to guidance. Do we find that the quantity of acquirement measures the quantity of insight? Is the amount of cardinal truth reached to be inferred from the mass of collected facts that serve as appliances for reaching it? By no means. Wisdom and information do not vary together. Though there must be data before there can be generalization, yet ungeneralized data, accumulated in excess, are impediments to generalization. When a man's knowledge is not in order, the more of it he has the greater will be his confusion of thought. When facts are not organized into faculty, the greater the mass of them the more will the mind stagger along under its burden, hampered instead of helped by its acquisitions. A student may become a very Daniel Lambert of learning, and remain utterly useless to himself and all others. Neither in this case, then, are results proportionate to appliances.

It is so, too, with discipline, and with the agencies established for discipline. Take, as an instance, the use of language. From his early days, the boy whose father can afford to give him the fashionable education, is drilled in grammar, practised in parsing, tested in detecting errors of speech. After his public-school career, during which words, their meanings, and their right applications, almost exclusively occupy him, he passes through a university where a large, and often the larger, part of his attention is still given to literary culture—models of style in prose and poetry being daily before him. So much for the preparation; now for the performance. It is notorious that commentators on the classics are among the most slovenly writers of English. Readers of *Punch* will remember how, years ago, the Provost and Head-master of Eton were made to furnish food for laughter by quotations from a letter they had published. Recently the Head-master of Winchester has given us, in entire unconsciousness of its gross defects, a sample of the English which long study of language produces. If from these teachers, who are literally the select of the select, we turn to men otherwise selected, mostly out of the same highly-disciplined class—

men who are distilled into the House of Commons, and then redistilled into the Ministry, we are again disappointed. Just as, in the last generation, royal speeches, drawn up by those so laboriously trained in the right uses of words, furnished for an English grammar examples of blunders to be avoided; so, in the present generation, a work on style might fitly take, from these documents which our government annually lays before all the world, warning instances of confusions, and illogicalities, and pleonasms. And then on looking at the performances of men not thus elaborately prepared, we are still more struck by the seeming anomaly. How great the anomaly is, we may best see by supposing some of our undisciplined authors to use expressions like those used by the disciplined. Imagine the self-made Cobbett deliberately saying, as is said in the last royal speech, that—

"I have kept in *view* the double *object* of an equitable *regard* to existing circumstances, and of securing a general provision more permanent in its character, and resting on *a reciprocal and equal basis*, for the commercial and maritime transactions of the two countries."[1]

Imagine the poet, who had "little Latin and less Greek," directing that—

"No such address shall be delivered in any place where the assemblage of persons to hear the same *may cause obstruction to the use of* any road or walk by the public."[2]

—a passage which occurs, along with half a dozen laxities and superfluities, in the eighteen lines announcing the ministerial retreat from the Hyde Park contest. Imagine the ploughman Burns, like one of our scholars who has been chosen to direct the education of gentlemen's sons, expressing himself in print thus:

"I should not have troubled you with this detail (which was, indeed, needless in my former letter) if it was not that I may appear to have laid a stress upon the dates which the boy's accident had prevented me from being able to claim to do."[3]

Imagine Bunyan the tinker publishing such a sentence as this, written by one of our bishops:

"If the 546 gentlemen who signed the protest on the subject of deaconesses had thought proper to object to my having formally licensed a deaconess in the parish of Dilton's Marsh, or to what they speak of when they say that 'recognition had been made' (I presume on a report of which no part or portion was adopted by resolution of the Synod) 'as to sisters living together in a more conventual manner and under stricter rule,' I should not have thought it necessary to do more than receive with silent respect the expression of their opinion," etc., etc.[4]

Or, to cite for comparison modern self-educated writers, imagine such a sentence coming from Alexander Smith, or Gerald Massey, or the

[1] Daily papers, February 7, 1873.
[2] *Times* and *Post*, February 11, 1873.
[3] *Times*, November 25, 1872.
[4] *Times*, November 27, 1872.

"Norwich Weaver-boy" (W. J. Fox), or the "Journeyman Engineer." Shall we then say that, in the case of literary culture, results are proportionate to appliances? or shall we not rather say that, as in other cases, the relation is by no means so simple a one.

Nowhere, then, do we find verified this assumption which we are so prone to make. Quantity of effect does not vary as quantity of means. From a mechanical apparatus up to an educational system or a social institution, the same truth holds. Take a rustic to see a new machine, and his admiration of it will be in proportion to the multiplicity of its parts. Listen to the criticism of a skilled engineer, and you will find that from all this complication he infers probable failure. Not elaboration but simplification is his aim; knowing, as he does, that every additional wheel and lever implies inertia and friction to be overcome, and occasional derangement to be rectified. It is thus everywhere. Up to a certain point, appliances are needful for results; but, beyond that point, results decrease as appliances increase.

This undue belief in appliances, joined with the general bias citizens inevitably have in favor of governmental agencies, prompts the multiplication of laws. It fosters the notion that a society will be the better the more its actions are everywhere regulated by artificial instrumentalities. And the effect produced on sociological speculation is, that the benefits achieved by laws are exaggerated, while the evils they entail are overlooked.

Brought to bear on so immensely complicated an aggregate as a society, a law rarely, if ever, produces as much direct effect as was expected, and invariably produces indirect effects, many in their kinds and great in their sum, that were not expected. It is so even with fundamental changes: witness the two we have seen in the constitution of our House of Commons. Both advocates and opponents of the first Reform Bill anticipated that the middle classes would select as representatives many of their own body. But both were wrong. The class-quality of the House of Commons remained very much what it was before. While, however, the immediate and special results looked for did not appear, there were vast, remote, and general results foreseen by no one. So, too, with the recent change. We had eloquently-uttered warnings that delegates from the working-classes would swamp the House of Commons; and nearly every one expected that, at any rate, a sprinkling of working-class members would be chosen. Again all were wrong. The conspicuous alteration looked for has not occurred; but, nevertheless, governmental actions have already been much modified by the raised sense of responsibility. It is thus always. No prophecy is safer than that the results anticipated from a law will be greatly exceeded in amount by results not anticipated. Even simple physical actions might suggest to us this conclusion. Let us contemplate one.

You see that this wrought-iron plate is not quite flat: it sticks up a little here toward the left—"cockles," as we say. How shall we flatten it? Obviously, you reply, by hitting down on the part that is prominent. Well, here is a hammer, and I give it a blow as you advise. Harder, you say. Still no effect. Another stroke? Well, there is one, and another, and another. The prominence remains, you see—the evil is as great as ever. But this is not all. Look at the warp which the plate has got near the opposite edge: where it was flat before it is now curved. A pretty bungle we have made of it. Instead of curing the original defect, we have produced a second. Had we asked an artisan practised in "planishing," as it is called, he would have told us no good was to be done, but only mischief, by hitting down on the projecting part. He would have taught us how to give variously-directed and specially-adjusted blows with a hammer elsewhere: so attacking the evil not by direct but by indirect actions. The required process is less simple than you thought. Even a sheet of metal is not to be successfully dealt with after those common-sense methods in which you have so much confidence. What, then, shall we say about a society? "Do you think I am easier to be played on than a pipe?" asks Hamlet. Is humanity more readily straightened than an iron plate?

Many, I doubt not, failing to recognize the truth that, in proportion as an aggregate is complex, the effects wrought by an incident force become more multitudinous, complicated, and incalculable, and that, therefore, a society is, of all kinds of aggregates, the kind most difficult to affect in an intended way and not in unintended ways—many such will ask evidence of the difficulty. Response would perhaps be easier were the evidence less abundant. It is so familiar as seemingly to have lost its significance; just as perpetually-repeated salutations and prayers have done. The preamble to nearly every act of Parliament supplies it; in the report of every commission it is presented in various forms; and, for any one asking instances, the direction might be—Hansard *passim*. Here I will give but a single example which might teach certain rash enthusiasts of our day, were they teachable. I refer to measures for the suppression of drunkenness.

Not to dwell on the results of the Maine Law, which, as I know from one who lately gave me his personal experience, prevents the obtainment of stimulants by travellers in urgent need of them, but does not prevent secret drinking by residents—not to dwell, either, upon the rigorous measures taken in Scotland in 1617, "for the restraint of the vile and detestable vice of drunkenness daily increasing," but which evidently did not produce the hoped-for effect—I will limit myself to the case of the Licensing Act, 9 George II., chapter 23, for the arresting the sale of spirituous liquors (chiefly gin) by prohibitory licenses:

"Within a few months after it passed, Tindal tells us, the commissioners of excise themselves became sensible of the impossibility or unadvisableness of carrying it rigorously into execution. . . . Smollett, who has drawn so dark a picture of the state of things the act was designed to put down, has painted in colors equally strong the mischiefs which it produced: 'The populace,' he writes, 'soon broke through all restraint. Though no license was obtained, and no duty paid, the liquor continued to be sold in all corners of the streets; informers were intimidated by the threats of the people; and the justices of the peace, either from indolence or corruption, neglected to put the law in execution.' In fact, in course of time, 'it appeared,' he adds, 'that the consumption of gin had considerably increased every year since those heavy duties were imposed.'"[1]

When in 1743 this Act was repealed, it was shown during the debates that—

"The quantity of gin distilled in England, which in 1684, when the business was introduced into this country, had been 527,000 gallons, had risen to 948,000 in 1694, to 1,375,000 in 1704, to 2,000,000 in 1714, to 3,520,000 in 1724, to 4,947,000 in 1734, and to not less than 7,160,000 in 1742. . . . Retailers were deterred from vending them (spirituous liquors) by the utmost encouragement that could be given to informers. . . . The prospect of raising money by detecting their (unlicensed retailers') practices incited many to turn information into a trade; and the facility with which the crime was to be proved encouraged some to gratify their malice by perjury, and others their avarice; so that the multitude of informations became a public grievance, and the magistrates themselves complained that the law was not to be executed. The perjuries of informers were now so flagrant and common, that the people thought all informations malicious; or, at least, thinking themselves oppressed by the law, they looked upon every man that promoted its execution as their enemy; and therefore now began to declare war against informers, many of whom they treated with great cruelty, and some they murdered in the streets."[2]

Here, then, with absence of the looked-for benefit, there went production of unlooked-for evils, vast in amount. To recur to our figure, the original warp, instead of being made less by these direct blows, was made greater; while other distortions, serious in kind and degree, were created. And beyond the encouragement of fraud, lying, malice, cruelty, murder, contempt of law, and the other conspicuous crookednesses named, multitudinous minor twists of sentiment and thought were caused or augmented. An indirect demoralization was added to a direct increase of the vice aimed at.

Joining with the prevalent fallacy that results are proportionate to appliances, the general political bias has the further effect of fostering an undue faith in political forms. This tendency to ascribe every thing to the visible proximate agency, and to forget the hidden powers without which the agency is worthless—this tendency which makes the child gazing at a steam-engine ascribe every thing to the combina-

[1] Craik, in "Pictorial History," vol. iv., p. 853. [2] Ibid.

tion of parts it sees, not recognizing the fact that the engine can do nothing without the steam-generating boiler, and the boiler nothing without the water and the burning fuel, is a tendency which leads citizens to think that good government can be had by shaping public arrangements in this way or that way. Let us frame our state-machinery rightly, they urge, and all will be well.

Yet this belief in the innate virtues of constitutions is as baseless as was the belief in the natural superiorities of royal personages. Just as, of old, loyalty to ruling men kept alive faith in their powers and virtues, notwithstanding perpetual disproofs, so, in these modern days, loyalty to constitutional forms keeps alive this faith in their intrinsic worth, spite of ever-recurring demonstration that their worth is entirely conditional. That those forms only are efficient which have grown naturally out of character, and that, in the absence of fit character, forms artificially obtained will be inoperative, are well shown by the governments of trading corporations. Let us contemplate a typical instance of this government.

The proprietors of a certain railway-company (I am here giving my personal experience as one of them) were summoned to a special meeting. The notice calling them together stated that the directors had agreed to lease their line to another company; that every thing had been settled; that the company taking the lease was then in possession; and that the proprietors were to be asked for their approval on the day named in the notice. The meeting took place. The chairman gave an account of the negotiation, and the agreement entered into. A motion approving of the agreement was proposed, and seconded, and to some extent discussed—no notice whatever being taken of the extraordinary conduct of the board. Only when the motion was about to be put, did one proprietor protest against the astounding usurpation which the transaction implied. He said that there had grown up a wrong conception of the relation between boards of directors and bodies of proprietors; that boards had come to look upon themselves as supreme, and proprietors as subordinate, whereas, in fact, boards were simply agents appointed to act in the absence of their principals, the proprietors, and remained subject to their principals; that, if, in any private business, an absent proprietor received from his manager the news that he had leased the business, that the person taking it was then in possession, and that the proprietor's signature to the agreement was wanted, his prompt return would be followed by a result quite different from that looked for—namely, a dismissal of the manager for having exceeded his duty in a very astonishing manner. This protest against the deliberate trampling down of principles recognized by the constitution of companies met with no response whatever: not a solitary sympathizer joined in the protest, even in a qualified form. Not only was the motion of approval carried, but it was carried without any definite knowledge of the agreement itself. Nothing more than the chairman's verbal description was vouchsafed: no printed copies of it had been previously circulated, or were to be had at the meeting. And yet, astonishing to relate, this proprietary body had been already once betrayed by an agreement with this same leasing company!—had been led to undertake the making of the line on the strength of a seeming guarantee, which proved to be no guarantee! See, then, the lesson. The constitution of this company, like that of companies in general, was purely democratic. The proprietors elected their directors, the directors their chairman; and there were special provisions for restraining directors and replacing them when needful. Yet these forms of free government had fallen into disuse. And it is thus in all cases. Save on occasions when some scandalous mismanagement or corruption, bringing great loss, has caused a revolutionary excitement among them, railway-proprietors do not exercise their powers. Retiring directors being reëlected as a matter of form, the board becomes practically a close body; usually some one member, often the chairman, acquires supremacy; and so the government lapses into something between oligarchy and monarchy. All this, observe, happening not exceptionally but as a rule, happens among bodies of men mostly well educated, and many highly educated—people of means, merchants, lawyers, clergymen, etc. Ample disproof, if there needed any, of the notion that men are to be fitted for the right exercise of power by teaching.

And now to return: Any one, who looks through these facts and facts akin to them for the truth they imply, may see that forms of government are valuable only where they are products of national *character*. No cunningly-devised political arrangements will of themselves do any thing. No amount of knowledge respecting the uses of such arrangements will suffice. Nothing will suffice but the emotional nature to which such arrangements are adapted — a nature which, during social progress, has evolved the arrangements. And wherever there is want of congruity between the nature and the arrangements —wherever the arrangements, suddenly established by revolution, or pushed too far in advance by reforming change, are of a higher type than the national character demands, there is always a lapse proportionate to the incongruity. In proof I might enumerate the illustrations that lie scattered through the modern histories of Spain, of South America, of Mexico. Or I might dwell on the lesson (before briefly referred to) presented us in France; where the recurring political cycle always shows us that new Democracy is but old Despotism differently spelt—where now, as heretofore, we find *Liberté, Egalité, Fraternité*, conspicuous on the public buildings, and now, as heretofore, have for interpretations of these words the extremest party-hatreds, vituperations and actual assaults in the Assembly, wholesale arrests of men unfriendly to those in power, forbiddings of public meetings, and suppressions of journals; and where now, as heretofore, writers, professing to be ardent advocates of political freedom, rejoice in these acts which shackle and gag their antagonists. But I will take, instead, a case more nearly allied to our own.

For less strikingly, and in other ways, but still with sufficient clearness, this same truth is displayed in the United States. I do not refer only to such extreme illustrations of it as were at one time furnished in California; where, along with that complete political freedom which some suppose to be the sole requisite for social welfare, most men lived in perpetual fear for their lives, while others prided themselves on the notches which marked, on the hilts of their pistols, the number of men they had killed. Nor will I dwell on the state of society existing under republican forms in the West, where a white woman is burnt to death for marrying a negro, where secret gangs murder in the night men whose conduct they dislike, where mobs stop trains to lynch offending persons contained in them, where the carrying of a revolver is a matter of course, where judges are intimidated and the execution of justice often impracticable. I do but name these as extreme instances of the way in which, under institutions that nominally secure men from oppression, they may be intolerably oppressed—unable to utter their opinions and to conduct their private lives as they please. Without going so far we may find in the Eastern States proof enough that the forms of liberty and the reality of liberty are not necessarily commensurate. A state of things under which men administer justice in their own cases, are applauded for so doing, and mostly acquitted if tried, is a state of things which has, in so far, retrograded toward a less civilized state; for one of the cardinal traits of political progress is the gradual disappearance of personal retaliation, and the increasing supremacy of a ruling power which settles the differences between individuals and punishes aggressors. And, in proportion as this ruling power is enfeebled, the security of individuals is lessened. That security, lessened in this general way, is lessened in more special ways, we see in the bribery of judges, in the financial frauds by which many are robbed without possibility of remedy, in the corruptness of New York administration, which, taxing so heavily, does so little. And, under another aspect, we see the like in the doings of legislative bodies—in the unfair advantages which some individuals gain over others by "lobbying" in Crédit-Mobilier briberies, and the like. While the outside form of free government remains, there has grown up within it a reality which makes government not free. The body of professional politicians, entering public life to get incomes, organizing their forces, and developing their tactics, have, in fact, come to be a ruling class quite different from that which the Constitution intended to secure; and a class having interests by no means identical with public interests. The worship of the appliances to liberty, in place of liberty itself, needs continually exposing. There is no intrinsic virtue in votes. The possession of representatives is not in itself a benefit. These are but means to an end; and the end is the maintenance of those conditions under which each citizen may carry on his life without further hindrances from other citizens than are involved by their equal claims—the securing to each citizen all such beneficial results of his activities as his activities naturally bring. The worth of the means is measured by the degree in which this end is achieved; and a citizen nominally having complete means, and but partially securing the end, is less free than another who uses incomplete means to more purpose.

But why go abroad for proofs of the truth that political forms are of worth only in proportion as they are vitalized by national character? We have proofs at home. I do not mean those furnished by past constitutional history—I do not merely refer to those many facts showing us that the nominal power of our representative body became an actual power only by degrees; and that the theoretically independent House of Commons took centuries to escape from regal and aristocratic sway, and establish a practical independence. I refer to the present time, and to actions of our representative body in the plenitude of its power. This assembly of deputies chosen by constituencies now so greatly extended, and therefore so well fitted, as it would seem, for guarding the individual, of whatever grade, against trespasses upon his individuality, nevertheless authorizes new trespasses upon his individuality. A popular government, just made more popular, has established, without the slightest hindrance, a law and an official organization that treat with contempt the essential principles of constitutional rule. Here is a brief account of the process:

On the 20th June, 1864, just before two o'clock in the morning, there was silently read a first time an act giving, in some localities, certain new powers to the police. On the 27th of that month, it was read a second time, also without comment—at what hour Hansard does not show. Just before two o'clock in the morning, on June 30th, there was appointed, without remark, a select committee to consider this proposed act. On the 15th July the report of this committee was received. On the 19th the bill was recommitted, and the report on it received—all in silence. On the 20th July it was considered—still in silence—as amended. And, on the 21st July, it was read a third time and passed—equally in silence. Taken next day to the House of Lords, it there, in silence equally profound, passed through all its stages in four days (? three). This act not proving strong enough to meet the views of naval and military officers (who, according to the testimony of one of the select committee, were the prompters of it), was in 1866 "amended." At one o'clock in the morning, on March 16th of that year, the act amending it was read a first time; and it was read a second time on the 22d, when the Secretary of the Admiralty, describing it as an act to secure the better health of soldiers and sailors, said: "It was intended to renew an act passed in 1864, with additional powers." And now, for the first time, there came brief adverse comments from two members. On April 9th there was appointed a select committee, consisting mainly of the same members as the previous one—predominantly state-officers, of one class or other. On the 20th, the report of the committee was received. On the 26th, the bill was recommitted, just before two o'clock in the morning; and on the report there came some short comments, which were, however, protested against on the ground that the bill was not to be publicly discussed. And then, to end this brief history, observe the reception given to the only direct opposition raised. When, to qualify a clause defining the powers of the police, it was proposed to add, "that the justices before whom such information shall be made shall in all cases require corroborative testimony and support thereof, other than that of the members of the police force," this qualification was negatived without a word.

And now, what was this act, passed the first time absolutely without comment, and passed in its so-called amended form with but the briefest comments, made under protest that comments were interdicted? What was this measure, so conspicuously right that discussion of it was thought superfluous? It was a measure by which, in certain localities, one-half of the people were brought under the summary jurisdiction of magistrates, in respect of certain acts charged against them. Further, those by whom they were to be charged, and by whose unsupported testimony charges were to be proved, were agents of the law, looking for promotion as the reward of vigilance—agents placed under a permanent temptation to make and substantiate charges. And yet more, the substantiation of charges was made comparatively easy by only requiring a single local magistrate to be convinced, by the testimony, on oath, of one of these agents of the law, that a person charged was guilty of the alleged acts—acts which, held to be thus proved, were punished by periodic examinations of a repulsive kind, and forced inclusion in a degraded class. A House of Commons, elected by large constituencies, many of which are now chiefly composed of working-men, showed the greatest alacrity in making a law under which, in sundry districts, the liberty of a working-man's wife or daughter remains intact only so long as a detective does not give evidence which leads a magistrate to believe her a prostitute! And this bill, which, even had there been something like adequate reasons (which we have seen there were not) for dispensing with precautions against injustice, should, at any rate, have been passed only after full debate and anxious criticism, was passed with every effort to maintain secrecy; and this on the pretext that decency forbade discussion of it—all the while that Mordaunt-cases and the like were being reported with a fulness proportionate to the amount of objectionable details they brought out! Nor is this all. Not only do the provisions of the act make easy the establishment of charges by men who are placed under a temptation to make them, but these men are guarded against penalties apt to be brought on them by abusing their power. A poor woman who proceeds against one of them, for making a groundless accusation ruinous to her character, does so with this risk before her: that, if she fails to get a verdict, she has to pay the defendant's costs (not taxed costs but *full* costs); whereas a verdict in her favor does not give her costs: only by a special order of the judge does she get costs! And this is the "even-handed justice" provided by a government freer in form than any we have ever had!"[1]

Let it not be supposed that in arguing thus I am implying that forms of government are unimportant. While contending that they are of value only in so far as a national character gives life to them, it is consistent also to contend that they are essential as agencies through which that national character may work out its effects. A boy cannot wield to purpose an implement of size and weight fitted to the hand of a man. A man cannot do effective work with the boy's implement: he must have one adapted to his larger grasp and greater strength. To each the implement is essential; but the results which each achieves are not to be measured by the size or make of the implement alone, but by its adaptation to his powers. Similarly with political instrumentalities. It is possible to hold that a political instrumentality is of value only in proportion as there exists a strength of character needful for using it, and at the same time to hold that a fit political instrumentality is indispensable. Here, as before, results are not proportionate to appliances; but they are proportionate to the force for due operation of which certain appliances are necessary.

One other still more general and more subtle kind of political bias has to be guarded against. Beyond that excess of faith in laws and in political forms which is fostered by awe of regulative agencies, there

[1] When, in dealing with the vitiation of evidence, I before referred to the legislation here named, I commented on the ready acceptance of those one-sided statements made to justify such legislation, in contrast with the contempt for those multitudinous proofs that gross abuses would inevitably result from the arrangements made. Since that passage was written, there has been a startling justification of it. A murder has been committed by a gang of sham-detectives (one of them a government employé); and the trial has brought out the fact that for the last three years the people of Lille have been subject to an organized terrorism which has grown out of the system of prostitute-inspection. Though, during those three years, five hundred women are said by one of these criminals to have fallen into their clutches—though the men have been blackmailed and the women outraged to this immense extent, yet the practice went on for the reason (obvious enough, one would have thought, to need no proof by illustration) that those aggrieved preferred to submit rather than endanger their characters by complaining; and the practice would doubtless have gone on still but for the murder of one of the victims. To some this case will carry conviction: probably not, however, to those who, in pursuance of what they are pleased to call "practical legislation," prefer an induction based on a Blue Book to an induction based on universal history.

is, even among those least swayed by this awe, a vague faith in the immediate possibility of something much better than now exists—a tacit assumption that, even with men as they now are, public affairs might be much better managed. The mental attitude of such may be best displayed by an imaginary conversation between one of them and a member of the Legislature.

"Why do your agents, with no warrant but a guess, make this surcharge on my income-tax return; leaving me to pay an amount that is not due, and to establish a precedent for future like payments, or else to lose valuable time in proving their assessment excessive, and, while so doing, to expose all my affairs? You leave me to choose between two losses, direct and indirect, for the sole reason that your assessor fancies, or professes to fancy, that I have understated my income. Why do you allow this? Why in this case do you invert the principle which, in cases between citizens, you hold to be an equitable one—the principle that a claim must be proved by him who makes it, not disproved by him against whom it is made? Is it in pursuance of old political usages that you do this? Is it to harmonize with the practice of making one whom you had falsely accused pay the costs of his defence, although in suits between citizens you require the loser to bear all the expense?—a practice you have but lately relinquished. Do you desire to keep up the spirit of the good old rulers who impressed laborers and paid them what they pleased, or the still older ones who seized whatever they wanted? Would you maintain this tradition by laying hands on as much as possible of my earnings and leaving me to get part of it back if I can: expecting, indeed, that I shall very likely submit to the loss rather than undergo the worry, and hindrance, and injury, needful to recover what you have wrongfully taken? I was brought up to regard the Government and its officers as my protectors; and now I find them aggressors against whom I have to defend myself."

"What would you have? Our agents could not bring forward proof that an income-tax return was less than it should be. Either the present method must be pursued, or the tax must be abandoned."

"I have no concern with your alternative. I have merely to point out that between man and man you recognize no such plea. When a plaintiff makes a claim but cannot produce evidence, you do not make the defendant submit if he fails to show that the claim is groundless. You say that, if no evidence can be given, nothing can be done. Why do you ignore this principle when your agents make the claim? Why from the fountain of equity comes there this inequity? Is it to maintain consistency with that system of criminal jurisprudence under which, while professing to hold a man innocent till proved guilty, you treat him before trial like a convict—as you did Dr. Hessel? Are your views really represented by these Middlesex magistrates you have appointed, who see no hardship to a man of culture in the seclusion of a prison-cell, and the subjection to prison-rules, on the mere suspicion that he has committed a murder?"

"The magistrates held that the rules allowed them to make no distinctions. You would not introduce class-legislation into prison-discipline?"

"I remember that is one of the excuses; and I cheerfully give credit to this endeavor to treat all classes alike. I do so the more cheerfully because this application of the principle of equality differs much from those which you ordinarily make—as when, on discharging some of your well-paid officials who have held sinecures, you give them large pensions, for the reason, I suppose, that their expensive styles of living have disabled them from saving any thing; while, when you discharge dock-yard laborers, you do not give them compensation, for the reason, I suppose, that out of weekly wages it is easy to accumulate a competence. This, however, by the way. I am here concerned with that action of your political system which makes it an aggressor on citizens, whether rich or poor, instead of a protector. The instances I have given are but trivial instances of its general operation. Law is still a name of dread, as it was in past times. My legal adviser, being my friend, strongly recommends me not to seek your aid in recovering property fraudulently taken from me; and I perceive, from their remarks, that my acquaintances would pity me as a lost man if I got into your Court of Equity. Whether active or passive, I am in danger. Your arrangements are such that I may be pecuniarily knocked on the head by some one who pretends I have injured his property. I have the alternative of letting my pocket be picked by the scamp who makes this baseless allegation in the hope of being paid to desist, or of meeting the allegation in Chancery, and there letting my pocket be picked, probably to a still greater extent, by your agencies. Nay, when you have, as you profess, done me justice by giving me a verdict and condemning the scamp to pay costs, I find I may still be ruined by having to pay my own costs if he has no means. To make your system congruous throughout, it only needs that, when I call him to save me from the foot-pad, your policeman should deal me still heavier blows than the foot-pad did, and empty my purse of what remains in it."

"Why so impatient? Are we not going to reform it all? Was it not last session proposed to make a Court of Appellate Jurisdiction by appointing four peers with salaries of £7,000 each? And has there not been brought forward this session, even quite early, a Government-measure for facilitating appeals; so that the final judgments may not be postponed from year to year? Give us a little time, and we will make these renewals of litigation much easier."

"Thanks in advance for the improvement. When I have failed to ruin myself by a first suit, it will be a consolation to think that I can complete my ruin by a second with less delay than heretofore. Meanwhile, instead of this reform which you seem to think of primary importance, I should be obliged if you would diminish the occasion for appeals, by making your laws such as it is possible for me to know, or, at any rate, such as it is possible for your judges to know; and I should be further obliged if you would give me easier remedies against aggressions, instead of remedies so costly, so deceptive, so dangerous, that I prefer suffering the aggressions in silence. Daily I experience the futility of your system. I start on a journey expecting (foolishly, I admit) that, in conformity with the advertised times, I shall just be able to reach a certain distant town before night; but the train, being an hour late at one of the junctions, I am defeated—am put to the cost of a night spent on the way, and lose half the next day. I paid for a first-class seat that I might have space, comfort, and unobjectionable fellow-travellers; but, stopping at a town where a fair is going on, the guard, on the plea that the third-class carriages are full, thrusts into the compartment more persons than there are places for, who, both by behavior and odor, are repulsive. Thus in two ways I am defrauded. For part of the fraud I have no remedy; and, for the rest, my remedy, doubtful at best, is practically unavailable. Is the reply that, against the alleged breach of contract as to time, the company has guarded itself, or professes to have guarded itself, by disclaiming responsibility? The allowing such a disclaimer is one of your countless negligences. You do not allow me to plead irresponsibility if I give the company bad money, or if, having bought a ticket for the second class, I travel in the first. On my side you regard the contract as quite definite; but, on the other side, you practically allow the contract to remain undefined. And now see the general effects of your carelessness! Scarcely any trains keep their times; and the result of chronic unpunctuality is a multiplication of accidents and loss of life."

"How about *laissez-faire?* I thought your notion was, that the less Government meddled with these things the better; and now you complain that the law does not secure your comfort in a railway-carriage, and see that you are delivered at your journey's end in due time. I suppose you approved of the proposal made in the House last session, that companies should be compelled to give foot-warmers to second-class passengers."

"Really, you amaze me. I should have thought that not even ordinary intelligence, much less select legislative intelligence, would have fallen into such a confusion. I am not blaming you for failing to secure me comfort or punctuality. I am blaming you for failing to enforce contracts. Just as strongly as I protest against your neglect in letting a company take my money, and then not give me all I paid for, so strongly should I protest did you dictate how much convenience should be given me for so much money. Surely I need not remind you that your civil law in general proceeds on the principle that the goodness or badness of a bargain is the affair of those who make it, not your affair; but that it is your duty to enforce the bargain when made. Only in proportion as this is done can men's lives in society be maintained. The condition to all life, human or other, is that effort put forth shall bring the means of repairing the parts wasted by effort—shall bring, too, more or less of surplus. A creature that continuously expends energy without return in nutriment dies; and a creature is indirectly killed by any thing which, after energies have been expended, habitually intercepts the return. This holds of associated human beings as of all other beings. In a society, most citizens do not obtain sustenance directly by the powers they exert, but do it indirectly: each gives the produce of his powers exerted in his special way in exchange for the produce of other men's powers exerted in other ways. The condition under which only this obtaining of sustenance, to replace the matter wasted by effort, can be carried on in society, is fulfilment of contracts. Non-fulfilment of contract is letting energy be expended in expectation of a return, and then withholding the return. The maintenance of contract, therefore, is the maintenance of the fundamental principle of all life under the form given to it by social arrangements. I blame you because you do not maintain this fundamental principle; and, as a consequence, allow life to be impeded and sacrificed in countless indirect ways. You are, I admit, solicitous about my life as endangered by my own acts. Though you very inadequately guard me against injuries from others, you seem particularly anxious that I shall not injure myself. Emulating Sir Peter Laurie, who made himself so famous by threatening to "put down suicide," you do what you can to prevent me from risking my limbs. Your great care of me is shown, for instance, by enforcing a by-law which forbids me to leave a railway-train in motion; and, if I jump out, I find that, whether I hurt myself or not, you decide to hurt me—by a fine.[1] Not only do you thus punish me when I run the risk of punishing myself, but your amiable anxiety for my welfare shows itself in taking money out of my pocket to provide me with various conveniences—baths and wash-houses, for example, and free access to books. Out of my pocket, did I say? Not always. Sometimes out of the pockets of those least able to afford it; as when, from poor authors who lose by their books, you demand *gratis* copies for your public libraries, that I and others may read them for nothing—Dives robbing Lazarus that he may give alms to the well-clad! But these many things you offer are things I do not ask; and you will not effectually insure me the one thing I do ask. I do not want you to ascertain for me the nature of the sun's corona, or to find a northwest passage, or to explore the bottom of the sea; but I do want you to insure me against aggression, by making the punishment of aggressors, civil as well as criminal, swift, certain, and costless to those injured. Instead

[1] *See* case in *Times*, December 11, 1872.

of doing this, you persist in doing other things. Instead of securing me the bread due to my efforts, you give me a stone—a sculptured block from Ephesus. I am quite content to enjoy only what I get by my own exertions, and to have only that information and those pleasures for which I pay. I am quite content to suffer the evils brought on me by my own defects—believing, indeed, that for me and all there is no other wholesome discipline. But you fail to do what is needed. You are careless about insuring to me the unhindered enjoyment of the benefits my efforts have purchased; and you insist on giving me, at other people's expense, benefits my efforts have not purchased, and on saving me from penalties I deserve."

"You are unreasonable. We are doing our best with the enormous mass of business brought before us: sitting on committees, reading evidence and reports, debating till one or two in the morning. Session after session we work hard at all kinds of measures for the public welfare—devising plans for educating the people; enacting better arrangements for the health of towns; making inquiries into the impurity of rivers; deliberating on plans to diminish drunkenness; prescribing modes of building houses that they may not fall; deputing commissioners to facilitate emigration; and so on. You can go to no place that does not show signs of our activity. Here are public gardens formed by our local lieutenants, the municipal bodies; here are light-houses we have put up to prevent shipwrecks. Everywhere we have appointed inspectors to see that salubrity is maintained; everywhere there are vaccinators to see that due precautions against small-pox are observed; and, if, happening to be in a district where our arrangements are in force, your desires are not well controlled, we do our best to insure you a healthy"—

"Yes, I know what you would say. It is all of a piece with the rest of your policy. While you fail to protect me against others, you insist on protecting me against myself. And your very failure to do the essential thing results from the absorption of your time in doing non-essential things. Do you think that your beneficences make up for the injustices you let me bear? I do not want these sops and gratuities; but I do want security against trespasses, direct and indirect—security that is real, and not nominal. See the predicament in which I am placed. You forbid me (quite rightly, I admit) to administer justice on my own behalf; and you profess to administer it for me. I may not take summary measures to resist encroachment, to reclaim my own, or to seize that which I bargained to have for my services: you tell me that I must demand your aid to enforce my claim. But demanding your aid commonly brings such frightful evils that I prefer to bear the wrong done me. So that, practically, having forbidden me to defend myself, you fail to defend me. By this my life is vitiated along with the lives of citizens in general. All transactions are impeded; time and labor are lost; the prices of commodities are raised. Honest men are defrauded, and rogues thrive. Debtors outwit their creditors; bankrupts make purses by their failures, and recommence on larger scales; and financial frauds that ruin their thousands go unpunished."

Thus far our impatient friend. And now see how untenable is his position. He actually supposes that it is possible to get government conducted on rational principles! His tacit assumption is that, out of a community morally imperfect, and intellectually imperfect, there may in some way be had legislative regulation that is not proportionately imperfect! He is under a delusion. Not by any kind of government, established after any method, can the thing be done. A good and wise autocrat cannot be chosen or otherwise obtained by a people not good and wise. Goodness and wisdom will not characterize the successive families of an oligarchy, arising out of a bad and foolish people, any more than they will characterize a line of kings. Nor will any system of representation, limited or universal, direct or indirect, do more than represent the average nature of citizens. To dissipate his notion that truly-rational government can be provided for themselves by a people not truly rational, he needs but to read election-speeches, and observe how votes are gained by clap-trap appeals to senseless prejudices, and by fostering hopes of impossible benefits, while votes are lost by candid statements of stern truths and endeavors to dissipate groundless expectations. Let him watch the process, and he will see that when the fermenting mass of political passions and beliefs is put into the electoral still, there distils over not the wisdom alone, but the folly also—sometimes in the larger proportion. Nay, if he watches closely he may suspect that not only is the corporate conscience lower than the average individual conscience, but the corporate intelligence too. The minority of the wise in a constituency is liable to be wholly submerged by the majority of the ignorant; often ignorance alone gets represented. In the representative assembly, again, the many mediocrities practically rule the few superiorities: the few superior are obliged to express those views only which the rest can understand, and must keep to themselves their best and farthest-reaching thoughts, as thoughts that would have no weight. He needs but to remember that abstract principles are pooh-poohed in the House of Commons, to see at once that, while the unwisdom expresses itself abundantly, what of highest wisdom there may be has to keep silence. And, if he asks an illustration of the way in which the intelligence of the body of members brings out a result lower than would the intelligence of the average member, he may see one in those muddlings of provisions and confusions of language in Acts of Parliament, which have lately been calling forth protests from the judges.

Thus the assumption that it is possible for a nation to get in the shape of law something like embodied reason, when it is not itself pervaded by a correlative reasonableness, is improbable *a priori* and disproved *a posteriori*. The belief that truly good legislation and administration can go along with a humanity not truly good, is a chronic delusion. While our own form of government, giving means for expressing and enforcing claims, is the best form yet evolved for preventing aggressions of class upon class, and of individuals on one another, yet it is hopeless to expect from it, any more than from other forms of government, a capacity and a rectitude greater than those of the society out of which it grows. And criticisms like the foregoing, which imply that its shortcomings can be set right by expostulating with existing governing agents or by appointing others, imply that subtlest kind of political bias which is apt to remain when the stronger kinds have been got rid of.

Second only to the class-bias, we may say that the political bias most seriously distorts sociological conceptions. That this is so with the bias of political party, every one sees in some measure, though not in full measure. It is manifest to the Radical that the bias of the Tory blinds him to a present evil or to a future good. It is manifest to the Tory that the Radical does not see the benefit there is in that which he wishes to destroy, and fails to recognize the mischiefs likely to be done by the institution he would establish. But neither imagines that the other is no less needful than himself. The Radical, with his impracticable ideal, is unaware that his enthusiasm will serve only to advance things a little, but not at all as he expects; and he will not admit that the obstructiveness of the Tory is a wholesome check. The Tory, doggedly resisting, cannot perceive that the established order is but relatively good, and that his defence of it is simply a means of preventing premature change; while he fails to recognize in the bitter antagonism and sanguine hopes of the Radical the agencies without which there could be no progress. Thus neither fully understands his own function or the function of his opponent; and, by as much as he falls short of understanding it, he is disabled from rightly understanding social phenomena.

The more general kinds of political bias distort men's sociological conceptions in other ways, but quite as seriously. There is this perennial delusion, common to Radical and Tory, that legislation is omnipotent, and that things will get done because laws are passed to do them; there is this confidence in one or other form of government, due to the belief that a government once established will retain its form and work as was intended; there is this hope that by some means the collective wisdom can be separated from the collective folly, and set over it in such way as to guide things aright—all of them implying that general political bias which inevitably coexists with subordination to political agencies. The effect on sociological speculation is to maintain the conception of a society as something manufactured by statesmen, and to distract attention from the phenomena of social evolution.

While the regulating agency occupies the thoughts, scarcely any thought is given to those astounding processes and results due to the energies regulated. The genesis of the vast productive and manufacturing and distributing agencies which has gone on spontaneously, often hindered, and at best only restrained, by governing powers, is passed over with unobservant eyes. And thus, by continually contemplating the power which keeps in order, and contemplating rarely, if at all, the activities that are kept in order, there is produced an extremely one-sided theory of society.

Clearly, it is with this as it is with the kinds of bias previously considered—the degree of it bears a certain necessary relation to the tempory phase of progress. It can diminish only as fast as society advances. A well-balanced social self-consciousness, like a well-balanced individual self-consciousness, is the accompaniment of a high evolution.

DOMESTIC ECONOMY OF FUEL.

By Captain DOUGLAS GALTON, C.B., F.R.S.

MY endeavor will be, to show that there may be obtained, from a much-diminished consumption of coal in fireplaces used for domestic purposes, all the advantages which have hitherto resulted from the wasteful expenditure which has prevailed.

I have no expectation of stating any thing that is actually new, because the functions and the attributes of heat and combustion have long been thoroughly discussed in their application to industrial objects. I hope, however, to draw attention to important considerations which govern the application of heat, and which are very generally neglected in fireplaces, in kitchen-ranges, and in most warming apparatus.

I think I may say, without hesitation, that the quantity of fuel now absolutely wasted in our houses amounts to at least five-sixths of the coal consumed. That is to say, if the greatest care and the best method of applying the heat were in all cases adopted, we could effect in heating and cooking all that we now effect, with one-sixth of the coal we now use; and, if, in the construction of our fireplaces and cooking apparatus, simple principles were recognized and ordinary care was used, we might without difficulty save from two-thirds to half of the coal consumed.

In my remarks on this question I intend to confine myself rather to the enunciation of the principles which should govern the application of heat for domestic purposes, than to give descriptions, except in a general way, of special appliances.

The inventors of apparatus for warming and cooking are so numerous, and the merits of a large number of inventions which have come into common use are of so negative a value, that it would not be fair to single out some individual instance for condemnation, and leave unnoticed other apparatus which possess equal defects and may be in equally extensive use. Mr. Edwards's very interesting and instructive treatise on domestic fireplaces clearly shows with what persistent perverseness the inventions which possess real merit have been almost invariably passed by. This result, I fear, is due mainly to the fact that architects and builders have not been penetrated with sound principles on the warming of our dwellings, and have encouraged the adoption of showy grates, based on false principles, instead of taking the trouble to make new designs of pretty grates based on sound principles of warming.

The question of the consumption of coal for domestic purposes divides itself into two branches:

1. The quantity required for warmth.
2. The quantity required for cooking.

The former is required only for the winter months, the latter is a permanent quantity during the year.

The waste of coal in domestic fireplaces is, however, no new question. It is quite eighty years since the subject was most fully treated of by Count Rumford, and afterward by Mr. Sylvester. They showed conclusively what enormous savings in fuel, for heating, cooking, and drying, were possible. Count Rumford's principles have never been generally applied, because the price of coals has ruled so low that householders have not much cared for economy. We hear Count Rumford's axioms now and then quoted by rival manufacturers in support of their newly-devised grates or kitchen-ranges; but, in many cases, the manufacturer, in the article he supplies, seems to be endeavoring to violate, rather than to follow, every axiom which Count Rumford ever laid down.

I do not mean to say that improvements have not taken place since Count Rumford's time, but the progress in the direction of economy has been very small, when we consider the great ingenuity displayed in devising new forms of apparatus. In respect of our fireplaces, our chief talent has been expended in providing a means of warming the outside air, and of polluting it by the smoke and soot we project into it.

The methods which have been adopted for warming houses fall under the several heads of—

1. Open fireplaces.
2. Close stoves (the German plan).
3. The Roman hypocaust, or floors warmed by direct action of fire.
4. Hot-water pipes, without ventilation.
5. Hot air warmed by a cockle, or by hot-water pipes.

The class of apparatus to be adopted in any country will vary with the climate. In England the climate is of so very changeable a nature, that the amount of heat required for comfort in a house varies from day to day. There are many days in the middle of winter when it is quite possible to sit in an unwarmed room; or, sometimes a warm morning is followed by a cold afternoon, when the sudden application of heat is desirable. It is probably for this reason that in England the open fireplace has, as a rule, held its own against all the proposals for warming houses by means of one central fire.

The open fireplace in ordinary use warms only by means of the direct radiation of the flame into the air of the room. It is the most primitive mode of warming, derived from the days when our ancestors inhabited caves. But these ancestors, by placing the fire in the centre of the floor of the cave, derived from it a larger portion of heat than we generally do, who place it against the wall of the room, and carry off the greater part of the heat up a flue separated from the room. The earlier fireplaces consisted of a large square brick opening, with a chimney carried up for the escape of smoke. The large square fireplace was adverse to the direct radiation into the room of the heat generated, and the large chimney removed from the room a very considerable quantity of air, which had necessarily to be replaced by cold air flowing into the room through all available apertures, and this created strong draughts.

Franklin, Count Rumford, and Sylvester, are the most prominent names of those who at an early period contributed improvements to the warming of our houses. The main principle of fireplace construction advocated by Count Rumford, eighty years ago, was, that the heat radiated from the fire directly into the room should be developed to the utmost. He brought the back of the fireplace as prominently forward as possible; he sloped the sides so as to reflect heat into the room; he advocated the use of fire-brick backs and sides instead of iron; he reduced the size of the chimney opening, so as to prevent the chimney carrying off the large quantity of warmed air it used to remove in his time. Our manufacturers of fireplaces have continued in the same groove. They have, undoubtedly, in some cases, largely developed the use of radiant heat. There are fireplaces, eminently successful as radiators of heat, of a circular or concave form, with polished iron sides, the fire being placed against a fire-brick back forming the apex of the concavity. So long as the concave surfaces are bright, the heat thrown out by them when a clear flame is burning is very great, but the gases from the flame pass directly off into the chimney while they are still at a very high temperature. The heat of the flame at that part will often be between 1,200° and 1,300° Fahr., and a very large proportion of this heat, to the extent of at least nine-tenths of that generated by the combustion of the fuel, is carried directly up the chimney.

One pound of coal is capable, if all the heat of combustion is utilized, of raising the temperature of a room, twenty feet square and twelve feet high, to ten degrees above the temperature of the outer air. If the room were not ventilated at all, and the walls were composed of non-conducting materials, the consumption of fuel to maintain this temperature would be very small, but, in proportion as the air of the room was renewed, so would the consumption of fuel necessary to maintain that temperature increase. If the volume of air contained in the room were changed every hour, one pound of coal additional would be required per hour to heat the inflowing air, so that, to maintain the temperature at ten degrees above that of the outer air during twelve hours, would require twelve pounds of coal.

The principle of the ordinary open fireplace is that the coal shall be placed in a grate, by which air is admitted from the bottom and sides to aid in the combustion of coal; and an ordinary fireplace, for a room of twenty feet square and twelve feet high, will contain from about fifteen to twenty pounds at a time, and, if the fire be kept up for twelve hours, probably the consumption will be about one hundred pounds, or the consumption may be assumed at about eight pounds of coal an hour.

One pound of coal may be assumed to require, for its perfect combustion, 150 cubic feet of atmospheric air; 8 lbs. would require 1,200 cubic feet; but, at a very low computation of the velocity of the gases in an ordinary chimney-flue, the air which would pass up the chimney at a rate of from 4 to 6 feet per second, or from 14,000 to 20,000 cubic feet per hour, with the chimneys in ordinary use, and I have often found a velocity of from 10 to 12 feet per second giving an outflow of air of from 35,000 to 40,000 cubic feet per hour—this air comes into the room cold, and when it is beginning to be warmed it is drawn away up the chimney, and its place filled by fresh cold air. A room 20 feet square and 12 feet high contains 4,800 cubic feet of space. In such a room, with a good fire, the air would be removed four or five times an hour with a moderate draught in the chimney, and six or eight times with a blazing fire; the air so removed would be replaced by cold air. The atmosphere of the room is thus being cooled down rapidly by the continued influx of cold air to supply the place of the warmer air drawn up the chimney. The very means adopted to heat the room produces draughts, because the stronger the direct radiation, or rather the brighter the flame in open fireplaces, the stronger must be the draught of the fire and the abstraction of heat. The only way to prevent draughts is to adopt means for providing fresh warmed air to supply the place of that removed.

The most natural way of providing warmed air is to utilize the excess of heat which passes up the chimney, beyond what is required for creating an adequate draught, and to use this heat to warm fresh air; and the warmed air should be admitted into the room in such places as will enable it to flow most easily into the currents prevailing in the room. These considerations led to the construction of the ventilating fireplace, which has been so extensively used in barracks. This fireplace will keep a room at a given temperature with one-third of the quantity of fuel usually required in most ordinary fireplaces, and with less than one-half the quantity required in the very best-constructed radiating fireplaces.

The open ventilating fireplace, if properly constructed, is the simplest and most effectual means of warming and ventilating a single room, because it absorbs all spare heat from the chimney beyond what is necessary to create a draught; and, while it admits warmed air into the upper part of the room in an imperceptible current, the action of the fire draws air from the lower part of the room, and thus provides for a circulation of the warmed air toward the floor of the room.

The ventilating fireplaces invented by me, and now called by my name, but which have never been the subject of a patent, were a consequence of the efforts made by the late Lord Herbert and Miss Nightingale to improve the health of the army. The death-rate of the soldiers, when this question was taken up, was found to be larger than that of many unhealthy civil populations. Soldiers are, however, a body of men picked out as the healthiest members of the nation; they should, therefore, have had an exceptionally low death-rate in peacetime. A main element in the improvement of their health lay in improving the ventilation of their barrack-rooms. But soldiers, whenever they became aware of the existence of any fresh-air currents, insisted on closing the inlets. It was also made a *sine qua non* by the Government that the barrack-rooms should be warmed by open fireplaces; and, moreover, the Government required that the increased amount of ventilation declared to be necessary on medical grounds should be provided without any increase in the amount of fuel allowed. By the adoption of these fireplaces, and by the introduction of simple and improved arrangements for cooking the soldiers' food, the Government were enabled to effect a saving on the fuel supplied, instead of being obliged to incur a large increased expenditure on account of the additional ventilation introduced into the barrack-rooms. The manufacturer of these fireplaces informs me that he has supplied between 9,000 and 10,000 to the military departments up to this time.

The principle of warming by means of an open fireplace, or by means of a German stove or a Gill stove, is applicable to single rooms, that is to say, each room must have its own appliance, and each room may be self-contained as far as regards its heating and ventilation.

The close stoves employed in Germany use less fuel in warming the room than any open fireplace, but they are economical because the heat generated is not removed by the frequent renewal of the air. This element of their efficiency in warming, however, makes them most unhealthy.

The most recent improvements in the use of the German stove for warming have been introduced by Dr. Böhm, in the Rudolf Hospital at Vienna. He there warms fresh air by means of passages constructed in the fire-clay stoves, placed in the ward, and the fresh warmed air passes into the ward from the top of the stove. He provides flues of a large size, and proportioned to the size of the ward, from the level of the ward floor to above the roof, and the difference of temperature between the air in the ward and the outer air causes a sufficient current in these flues to ventilate adequately the ward. By this means the fresh warmed air, instead of passing off to the upper part of the ward and then away by flues there, is made to circulate toward the floor of the ward, thus bringing into action the principle by which the open fireplace is useful in ventilation. But this arrangement destroys one element of economy in the German stove, because the heat generated, instead of being left to pass slowly off into an unventilated room, is removed rapidly by the fresh air passed into the ward, and has, therefore, to be renewed at intervals, instead of, according to usual custom, the stove being left shut up for twenty-four hours to give off its heat slowly. The larger the supply of warmed air, the larger must be the consumption of fuel; and, if the heat is to be supplied economically, it must be through a good conducting medium; but the material of the German stove is a bad conductor of heat.

The old Roman system of warming by means of a fire under the floor produced a most agreeable and equable temperature, but it did not assist the ventilation, and it was not economical, in that the floor, being of tiles, was of a bad conducting material, and much of the heat was absorbed in the ground or surrounding flues. According to Pliny, the smoke was carried to the wood-house to be used in drying the wood for burning. I recently made an experiment to compare the effect of warming by means of a heated floor with the heating effect of a ventilating fireplace; the experiment lasted, with each mode of warming, for two days. It showed that, in the case of the warmed floors, the room was maintained at a temperature of about 18° above the temperature of the outer air with an expenditure of 56 lbs. of coal and 112 lbs. of coke, while with the ventilating fireplace the expenditure was only 75 lbs. of coal; the cost being 3*s.* 4*d.* for the warmed floor as compared with 1*s.* 4*d.* for the ventilating fireplace.

A more complete plan of warming a building is by means of a fire from which the heat is conveyed, either by hot-water pipes or hot air, to the various parts of the building.

Warming by means of air conveyed by flues to various parts of the building, will answer, as a rule, in ordinary existing houses, best in connection with open fireplaces, which draw in the warmed air to the various rooms, because there must be some means of forcing or drawing the warmed air into the house, and it would not be convenient to keep a steam engine in an ordinary house to pump in the warmed air. These open fireplaces would then, however, be wasting the spare heat which each fireplace sends up its own chimney; but, on the other hand, very much smaller fires would be needed, to keep the rooms warm, than when the rooms are not supplied with fresh warmed air. Theoretically, however, it can be shown that if we are prepared to give up open fireplaces, and arrange our houses on the plan of having flues which would draw off the air from near the floors of our rooms, and which would also warm fresh air, heated from a central fire, to be constantly admitted near the ceilings, and if the climate were such as to make us desire to have the system in continuous operation, such a system would probably be by far more economical of fuel than open fireplaces, because the fuel used could then be made to do its full duty. The variations of our climate and the low price of fuel, which have hitherto prevailed, have prevented such systematic arrangements from being adopted in this country.

The plan of carrying the heat from the fire to the air to be warmed by means of hot-water pipes affords also a very economical method of warming air, because the best-constructed hot-water apparatus will enable the full heating value to be got out of the fuel. Fuel may be consumed to far greater advantage in a close furnace than in any open grate, because the admission of air for the combustion of the fuel can be regulated to any required extent. The heating surface of the boiler may also be so arranged as to absorb a very large proportion of the heat generated by the fire.

But in deciding on the amount of heat in hot-water pipes which is most favorable to economy, the following considerations occur: At least twice the quantity of air which is strictly necessary by theory passes through the fire in the best-constructed furnaces. In an ordinary grate this consumption is enormously increased. Each part of oxygen supplied by the air and necessary for combustion is accompanied by four parts of nitrogen, which is of no value for combustion. Consequently, if twice as much oxygen passes through the fire as is strictly necessary, we have one part which combines with carbon and produces combustion, and nine parts which, being inert, must act, in the first place, to lower the temperature of the fire, and, secondly, to carry a larger amount of unutilized heat up the chimney. Moreover, when water is heated sufficiently to generate steam, each particle of water converted into steam absorbs or makes latent 960° Fahr. of temperature. In experiments on the evaporation of water, the temperature of the gases passing off in the chimney was ascertained to vary from 430° to 530°, diminishing to 415° at the top of a flue 35 feet high, with the dampers open; and about 380° at the bottom of the flue with the dampers closed. With a boiler of which the temperature of the water is maintained at 200° without evaporation, the temperature of the flue need not exceed from 230° to 240°.

It is clear from these considerations, that, in order to insure the maximum effect from the fuel, the heating surface of the pipes should be sufficiently large to warm all the air required without its being necessary to raise the temperature of the water in the boiler to any great extent, and the proportion between the boiler-surface and the pipe-surface, that is to say, between the surface which absorbs heat, and the surface which gives out heat, should be such as to render it unnecessary for the fire to be forced, because, the lower the temperature at which the gases from the fire pass off up the chimney, the greater will be the economy.

In order to show the waste which results from forcing the boiler, i. e., from passing the gases into the flue at a high as compared with a low temperature, I will give an instance of one experiment. The proportion of heating surface in the boiler to the heating surface of the pipes is assumed by some manufacturers as 1 to 100, or, when great heat is required, 1 to 40. An experiment made on 4,000 feet of pipe, heating certain greenhouses by a wagon-shaped boiler with 40 square feet of heating surface, showed that a certain temperature was kept up for 8 hours with 8 bushels of coal; but when, by the addition of another boiler, the heating surface of the boiler was increased to 80 square feet, the temperature could be maintained for the same period with 4 bushels of coal. The outer temperature was the same on the two days.

On these grounds it is not so economical, so far as the consumption of fuel is concerned, to use steam instead of water, either water heated to a high temperature under pressure, or to heat air for warming purposes, because the gases from the fire employed to produce the higher degree of heat will pass off at a high temperature, and the heat they contain be wasted. On the other hand, the capital outlay required, where highly-heated pipes are used, is smaller than with hot-water pipes, because a smaller heating surface, and therefore smaller pipes, will suffice when the temperature is high; and, moreover, a very small pipe will convey steam to any required place, whereas with hot water, at a relatively low temperature, much larger pipes are required. It follows that where the price of fuel makes it necessary to reduce the permanent annual expenditure, the original capital outlay must be increased. There is a further consideration in regard to economy with hot-water pipes, steam-heating, and all appliances for warming buildings from a central fire, viz., that if the heat has to be conveyed for long distances before its useful application comes into force, very much heat is lost, and consequently fuel is wasted. On the other hand, against the saving which would result from a more immediate application of the heat to the place to be warmed, there is to be weighed the diminished expense of attendance consequent upon the use of one fire instead of several fires, each with its attendance and supply of fuel. There remains one source of economy to be applied to close grates used for heating water, which has not yet been adopted. I mean the application of some of the heat which is passing into the chimney to warm the air which feeds the fire. Theoretical considerations show that an advantage of from six to nine per cent. might be obtained from this source, and the experiments which I have made bear out this result.

But, after we have designed the most effective arrangements for economizing the fuel which warms our dwellings, if that object is to be fully secured, we must arrange to retain the heat in our houses. The architect should devote to these considerations the same care which he now is frequently satisfied with bestowing upon the beauty of the design for a building. The arrangements of the plan should be adapted to the retention of heat. All portions of houses exposed to the air should be formed of materials which are found to be the slowest conductors of heat. Whatever may have been the mistakes of the manufacturers of fire-grates or kitchen-ranges, the nation has latterly very much disregarded the means of retaining heat in the house. The uniform model house of the speculating builder is constructed with thin walls, thin glass windows, ill-fitting casements, and a roof of slates, with nothing under them. The old half-timbered house was warm, because it had an air space between the inner and outer skin; the brick-built, stone-faced house is warm because it has, so to say, a double wall. In modern houses it has long been shown that, without much increased expense, the use of walls built hollow will keep the rooms effectually warm and dry, and yet this mode of building is the exception rather than the rule, possibly because it gives the architect or the builder a little additional trouble. A slated roof, if ill-constructed, is a material agent in allowing of the escape of heat, because there is necessarily an inlet for air where the slates overlap. The old thatched roof, although most dangerous in cases of fire, was a great preserver of heat. In well-built modern houses the slates are laid on felt, which is laid on close boarding, and this arrangement keeps the house warm in winter and cool in summer. As regards the windows, glass ranks high as a non-conductor of heat, and the effect of using thick glass, instead of the very thin glass so often seen, is very largely to economize the heat. Evidence of the cooling effect on the air of a room of a window of thin glass is afforded by the cold draught which any one perceives when sitting on a cold day near a closed window of thin glass. Proposals have been often made to glaze a window with double panes, and no doubt such a plan is a good means of retaining heat in the room, but the inside of the glass between the panes will in time become dirty, and then it can only be cleansed by removing one of the panes. A more convenient, but more expensive, plan is to adopt the system, which prevails universally in the northern parts of Europe, of a double casement.

It is not, however, my object here to give a treatise on building. The conclusion which I would draw from these various considerations is, that, if we desire to economize to the utmost the daily expenditure of fuel, we must increase our outlay of capital. So long as coal was cheap, it may have been better worth the while of the individual consumer to employ coal wastefully rather than spend money upon the arrangements for economizing heat. On the other hand, when coal is dear, the daily expense from the waste of fuel will induce a capital outlay to secure economy of heat.—*Journal of the Society of Arts.*

THE DRIFT-DEPOSITS OF THE NORTHWEST.

By N. H. WINCHELL,

STATE GEOLOGIST OF MINNESOTA.

I. *Nature of the Drift.*

IN the March number of this journal, Mr. Elias Lewis calls attention to the occurrence of bowlder-like masses of clay in stratified gravel, at Brooklyn, N. Y. In the progress of the geological survey of Ohio, similar masses of gravelly clay were met with in the northwestern portion of the State, lying in the stratified gravel and sand that constitute the long ridges which have often been pronounced "lake-beaches." These occurrences, and a great many others that militate against the popular theory that those ridges are attributable to the action of the waters of Lake Erie, and the stratification of the drift generally over the "interior continental basin" to the action of a wide-spread lake, or of the ocean, made it necessary to reinvestigate the drift-deposits thoroughly, for the purpose of deducing from the drift itself such a theory of its origin as would stand the application of all the facts. Such reëxamination has resulted, in the opinion of the writer, in the confirmation of the glacier theory of Prof. L. Agassiz, and the consequent abandonment of the iceberg theory of Peter Dobson. It has also shown the baselessness of the assumption of some who would extend the Champlain epoch of Prof. J. D. Dana, so as to bring on, after the period of the glacier, a submergence of the continent beneath the ocean. It is proposed to review, in a non-technical way, the phenomena of the drift of the Northwest, and to offer a few thoughts on the *glacier theory*, and its application to the explanation of those phenomena.

In general, the term drift applies to whatever lies on the surface of the rocky framework unconsolidated, whatever be its origin or lithological character. Glacial drift is that which has been transported by the agency of ice, or by ice and water, from regions farther north, and spread over the surface of the country. It may embrace bowlders, gravel, and clay. These substances may be arranged in stratification, and nicely assorted, or they may be confusedly mixed.

When stratified and assorted, they have sometimes been denominated *modified drift;* when not assorted, *unmodified drift.* But these terms require considerable caution in their use, since they have been differently applied by different writers, depending somewhat on the supposed cause of the assortment witnessed in *modified drift*, and since the assorted and non-assorted portions of the drift are not uniform, either in their positions in the great mass of the deposit, or in the characters they generally possess.

The character and nature of the drift in the Northwest are very largely misapprehended. This is true, not only among those who might not strictly be regarded as geologists—such as surveyors, engineers, lecturers, and public *literati*—but even among those who have given considerable attention to the study of fossils and rocks. These misapprehensions, so generally spread among the people, are largely due to the industry of the authors of certain theories concerning its origin, in spreading their views before the public. A plausible theory, moreover, has a great influence in its own favor.

A pretty careful study of the drift in this State,[1] and in others embraced in what may be called the *continental basin*, east of the Mississippi, has shown it to consist, in general, of the following parts, in descending order:

No. 1. *Surface Soil.*—This, of course, presents all the varieties due to local influences. Over large portions of the Northwest it is a fertile black loam, highly arenaceous, and supplied with a considerable proportion of carbon in a state of minute subdivision. This arenaceous loam passes into a more gravelly loam on the brows of knolls and in rolling land. It is also sometimes replaced by a gravelly clay. This is the case in large portions of the State of Michigan, and in Central and Southern Ohio. This is the fact in Northern Indiana and in Central Minnesota. The gravel prevails in wooded and rolling districts. In treeless districts the sandy element is more common, making a black loam. In valleys and along streams the soil is alluvial. It is invariably fine, nearly free from stones and bowlders, and very fertile. It is what is popularly known as "made land," and comprises those parts of the drift of the highlands that are susceptible of transportation by running water. That which is known as the "bluff-formation," lining the Mississippi, both in Minnesota and in the States farther south, consists of alluvium, washed into the great valley by innumerable streams from the adjoining country, at a time when the volume of the river was immensely greater than now. The same materials are now spread over the farms of Southern Minnesota, over much of Iowa and Illinois, over Northern Missouri and all the Far West, to the Rocky Mountains. It lies there also in the form of fine sand, and constitutes the *loam* already described. Its thickness at points remote from the river is dependent on the facilities for natural drainage and wash. It may be

[1] Minnesota.

six inches, or it may be six feet. Along the banks of the Mississippi it presents, not infrequently, perpendicular sections of six hundred feet. Its firmness in maintaining its position in such exposed bluffs is due to the infiltration of the cements of lime and iron while in the process of deposition, or subsequently. It is more largely developed along the Missouri than along the Mississippi. There are other places where the surface-soil may be peaty, from the preservation of dead vegetation. Extensive level tracts, that are submerged a large part of the year, may present a peaty soil. Very often also in such peaty places there will be found patches of highly-calcareous soil, resulting from the accumulation of fresh-water shells, or from the precipitation of the carbonate of lime from waters that enter the marsh from limestone districts.

But, whatever the character of the surface-soil, it must be borne in mind that it is accidental, and is always superinduced by causes that have operated since the advent of the drift. Its influence is strictly superficial, rarely exceeding three feet below the natural surface.

No. 2.—We come now to consider that which lies below the surface-soil. If we omit from this enumeration the "bluff-formation," and the alluvium of other streams which sometimes has a considerable thickness, we shall have two different substances, equally pertaining to the drift, and occupying the same relative position in different localities, that claim notice:

1. A *clay* subsoil.
2. A *gravel* or *sand* subsoil.

Now, although these are mentioned as appearing first beneath the surface-soil, it must not be understood that they appear there invariably, nor even usually. It is probably true that throughout the greater portion of the Northwest they are entirely wanting, and that feature of the drift prevails which will next be considered. They are mentioned here because they constitute an essential part of the drift, and must not be overlooked in giving its character and composition.

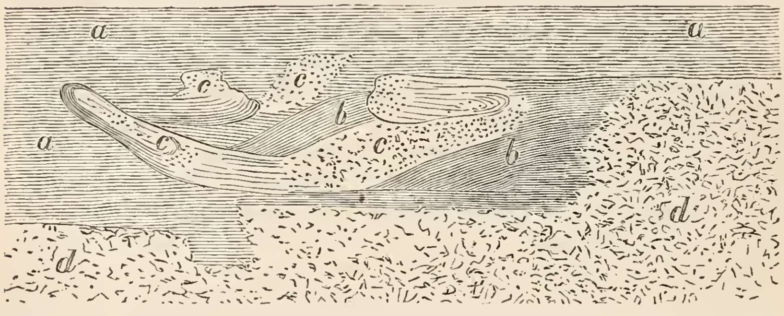
By the first, here denominated a *clay* subsoil, is not meant a gravelly clay, or one in which stones are present. It is, rather, a close, plastic, fine clay, with little observable sand. It is impervious to water, and is benefited by artificial drainage. It prevails in much of Southwestern Michigan and Northwestern Ohio. It occupies a large tract in Northeastern Illinois and Northwestern Indiana. It also probably underlies the Red River flats in Minnesota, and perhaps a belt of land rudely conforming to the shore of Lake Superior at its western extremity. When shafts are sunk through this clay subsoil, so as to reveal its composition and arrangement, it is seen to be handsomely laminated horizontally. The individual layers are separated by thinner layers of fine sand. Those of clay are usually about two inches in thickness, but may be no more than one-eighth of an inch; the layers of sand are rarely more than half an inch in thickness, and are apt to be less than an eighth. The aggregate thickness of these alternating layers of clay and sand is sometimes a hundred feet or more. Let it be noticed that these areas of *clay subsoil* are those in which there is a gentle descent, and drainage to the north or northeast into some one of the great interior lakes of fresh water. The relation this fact bears to the origin of this *clay subsoil* will be considered farther on.

The *gravel* or *sand* subsoil is that which is found in some tracts of rolling land where the drift is heavy, and at points more remote from the valleys of northward drainage, or in the upper portions of those valleys. As a general rule, when present, it will be found on a higher level than that in which the subsoil is clay. It pertains to the interior country like the central part of the southern peninsula of Michigan, the central and southern portions of Ohio, Indiana, and Illinois, and some parts of Central and Northern Minnesota. The area and location of this kind of subsoil are more irregular and more uncertain than the areas of clay subsoil. Such gravel and sand deposits often lie in belts traceable for a great many miles, especially where the general surface is smooth, and the underlying rock of uniform hardness, the country adjoining being, on either side of the belt, one of a clay subsoil, or one formed by No. 3. Such belts are sometimes three or four rods wide, or they may be much wider, and are rolling and slightly raised above the adjoining clay land. Sometimes, instead of lying in belts, such rolling, gravelly land is spread out over areas of no definite shape or limit. The sand or gravel constituting the subsoil in these rolling tracts is, like the clay of the clay subsoil, stratified and assorted. But the layers here are rarely horizontal. They show the most various alternation and change of dip. No two sections could be taken that would give the same succession of parts. The sand sometimes lies in heavy deposits fifteen or twenty feet thick, with lines of deposition running in curving and vanishing layers in all directions. Sudden transitions occur from sand to gravel, or from gravel to bowlders. Sometimes, also, bowlders are found embedded in the gravel; again, nests of bowlders are seen isolated from the rest, and packed closely by themselves. There is also very often a mingling of gravel and sand, with no clay, without stratification, as if the two had been dumped together, after having been first thoroughly washed and assorted. Occasionally, also, in this stratified gravel and sand, may be seen irregular masses of gravelly clay or hard-pan, comparable to those mentioned by Mr. Lewis at Brooklyn. Such gravelly clay sometimes embraces stones of considerable size. Near the bottom of this stratified gravel and sand there are also, often, upward protrusions of the underlying member of the drift (No. 3), somewhat wedge-shaped or oblique, so as to embrace on the lower side a portion of the stratified gravel and sand. Again, the line of junction between the gravel and sand, and the hard-pan of No. 3, may be marked by an unusual accumulation of coarse drift materials, such as stones and bowlders. These may be mostly surrounded by the gravel and sand of No. 2, or they may be mostly embedded in No. 3. The thickness of No. 2 is exceedingly variable. It is usually less than forty feet in level tracts, but it may be more than a hundred, depending on the duration of the cause that brought it there, and its operation at that point. It sometimes probably entirely replaces No. 3 and No. 4, and lies on the rock. The bowlders found within it are generally not scratched, but sometimes they are scratched, evidently by glacier-action. A great number of glaciated bowlders in this member of the drift have been seen at an excavation near the Falls of St. Anthony.

The following diagrams, Figs. 1 and 2, will express more fully the arrangement of the strata in this member of the drift, and give an idea of the manner of union with the succeeding member below. Fig. 1 is sketched from Nature, and shows a section of the laminated clay exposed in a railroad-cut near Toledo, Ohio:

Fig. 1.

NATURAL SURFACE.



SECTION OF THE LAMINATED CLAY (CLAY SUBSOIL), TOLEDO, OHIO, SHOWING ITS JUNCTION WITH THE HARD-PAN OF THE DRIFT.

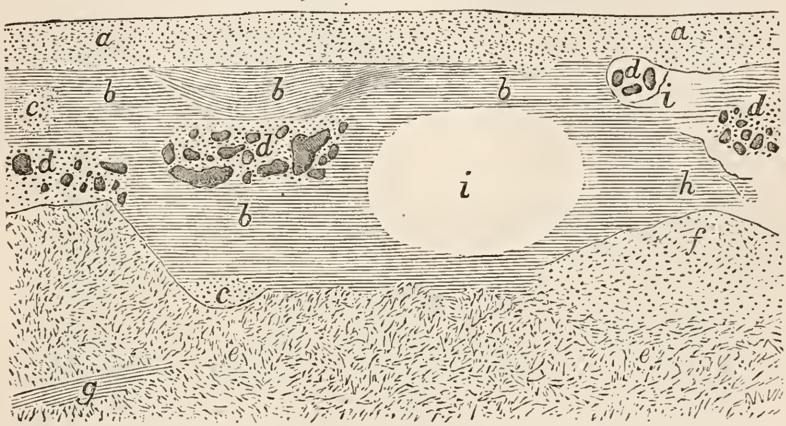
a. Horizontal laminations of fine clay and sand.
b. Oblique laminations of fine clay and sand.
c. Detached masses of hard-pan clay, variously mingled and united with the laminated clay.
d. The upper portion of the great hard-pan sheet.

Fig. 2 is also sketched from Nature, and represents the alternation of parts as seen in No. 2, and manner of junction with No. 3 at the Falls of St. Anthony. No. 2 here consists of the stratified gravel and sand which constitutes the surface of the drift (immediately below the soil) in large portions of the State of Michigan, Central and Southern Ohio, Northern Indiana, and Central Minnesota. It also forms the principal component of the well-known ridges in Northwestern Ohio, popularly but erroneously styled "lake-beaches." The materials are usually much water-worn, but, at the Falls of St. Anthony, many of the bowlders embraced in No. 2 are conspicuously glacier-marked, a circumstance which plainly indicates the agency which transported and deposited the whole mass in which they occur.

No. 3.—The great deposit that follows No. 2, whether it be of clay or of gravel and sand, is that designated in common usage "hard-pan." It constitutes the chief member of the drift throughout the Northwest. It is rarely found entirely wanting, whereas the foregoing are very often wanting. It seems to be the parent member of which the former two are offshoots, or modifications. It sometimes has a thickness of more than two hundred feet, and rises to the surface forming the basis of the soil. It consists of a heterogeneous mixture of clay and gravel-stones, with bowlders of northern origin. It is nearly impervious to water, and occasionally, but rarely, shows a rude arrangement in alternating bands, as if, in a plastic state, it had been folded upon itself. Such arrangement discloses no assortment of the

Fig. 2.

NATURAL SURFACE.



Section of the Drift at the Falls of St. Anthony.

a. "Bluff-formation," alluvial, unstratified, mostly sand.....6– 8 feet.
b. Stratified, fine sand.......................................6–20 do.
c. Gravel and stones, in isolated pockets, unstratified.
d. Bowlders and gravel, the former distinctly glaciated.
e. Hand-pan, or "unmodified" drift......................seen 10 do.
f. Massive, fine sand.
g. Rude arrangement within the hard-pan.
h. Sandy and stony, with rude stratification.
i. Hid from view by sliding sand.

materials that can be likened to the assortment seen in No. 2. The bowlders embraced in this member of the drift almost invariably show glaciated surfaces. Although apt to be more abundant near the bottom of the deposit, they are not confined to it, as is sometimes stated, but occur throughout the whole. This deposit of hard-pan sometimes encloses lenticular masses of assorted materials. It has even been seen to overlie a considerable thickness of fine stratified sand the extent of which could not be ascertained. In general, however, it is one compact, uniform mass, varying slightly in the proportions of its different parts, from State to State, according to the readiness of supply of any

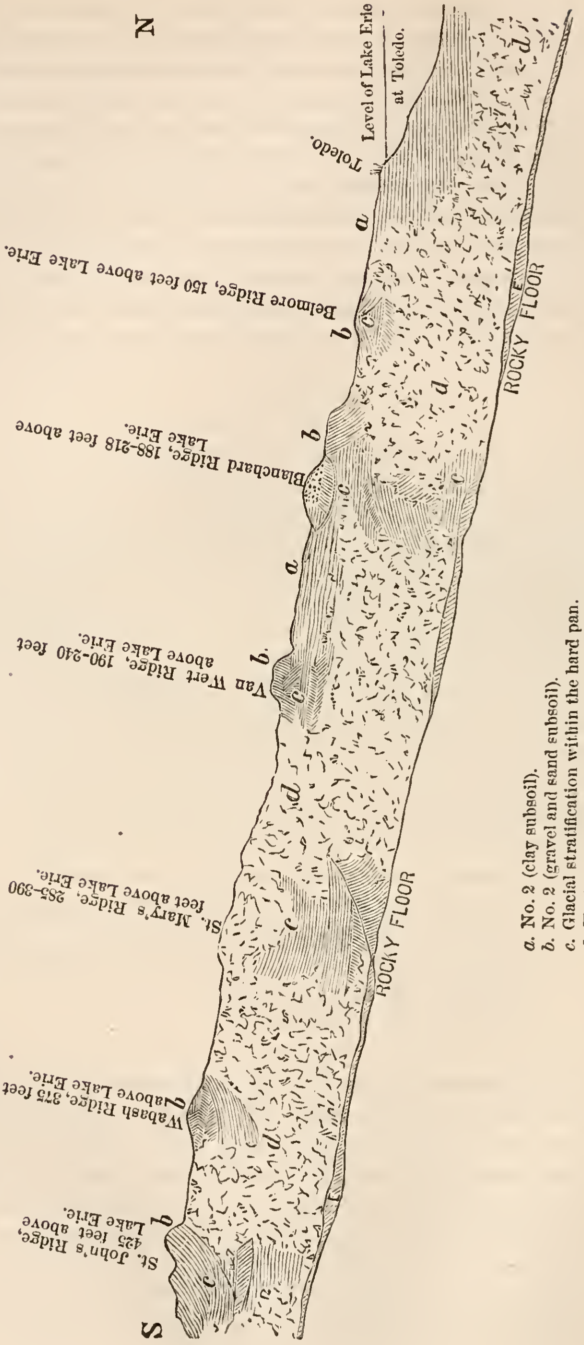


Fig. 3.

GENERAL SECTION OF THE DRIFT FROM TOLEDO, OHIO, TO SHELBY COUNTY, OHIO.

a. No. 2 (clay subsoil).
b. No. 2 (gravel and sand subsoil).
c. Glacial stratification within the hard pan.
d. Hard pan, glacier drift, holding striated bowlders.—(No. 3.)
e. Gravel, sand, and bowlders, holding water.—(No. 4.)

one of them. For example, in Ohio (Northwestern Ohio) it is very close and clayey, the upper part being free from bowlders and stones. In Minnesota (Central Minnesota), the stones and bowlders are more generally disseminated throughout the whole, and it shows much more sand. Hence, in the latter State it will allow the slow passage of water through it—a fact exceedingly fortunate for the agricultural capacity of the soils that are based on it.

Perhaps there should be added to this description of the drifts another member, which may be denominated No. 4.

No. 4.—This, however, is so inconstant and so often runs into the last, that it is hardly worthy of special designation. When present, it lies below No. 3, and immediately over the rock. It consists of gravel and bowlders, more or less mingled with clay. It is the great water-reservoir that supplies deep wells, and through it there is a constant slow drainage into deep valleys and excavations. It gives rise to springs at the base of the river-bluffs, and to artesian wells, when the confining stratum of hard-pan above is penetrated in regions of favorable slope. In Northwestern Ohio is a most wonderful series of artesian wells that depend entirely upon this fortunate combination of circumstances. This member of the drift sometimes consists largely of assorted materials, as sand and gravel. This is indicated by the issuing of considerable quantities of such sand from artesian wells that penetrate it, when the force of the current of water is sufficient to bring it to the surface. Instances have occurred of the collapse of the overlying clay and hard-pan, on the removal in this way of large quantities of sand. Along the upper side of this member, the materials are apt to be firmly cemented by iron and carbonate of lime, into a very firm, even rocky crust. Such cemented gravel and sand is seldom over two feet thick, yet well-borers, on reaching it, often mistake it for the bed-rock. They pass through it, and usually find a copious flow of excellent water. The announcement is then promulgated that *that well was drilled through the rock*. Hence it is a popular error that, in order to obtain water of the purest quality, it is necessary to sink a well "through the rock." This member, though, is not always found in penetrating the drift to the rock. It may be here stated, also, that, when No. 4 is present, the bed-rock does not show so plainly the marks of glaciation; but, when No. 3 extends to the rock, the surface of the bed-rock is almost invariably marked with the well-known glacier-etchings.

Having taken this survey of the component parts of the drift, it will be well to bring them into a general view, as illustrated by the preceding diagram (Fig. 3), in which the figures represent the same members as in the previous illustrations. It shows a general section of the drift, from Toledo to Shelby County, Ohio, and is based on extended observations, the results of which are to appear in the forthcoming reports of the "Geological Survey of Ohio." The six ridges here represented in profile can be traced from 30 to 130 miles, running into Indiana. Toward the north, in Michigan, they unite by convergence, but one or two being visible in that State. Another article will treat the interesting question of the origin of the drift.

SOME OBSERVATIONS ON NIAGARA.[1]

By Prof. JOHN TYNDALL, LL.D., F.R.S.

IT is one of the disadvantages of reading books about natural scenery that they fill the mind with pictures, often exaggerated, often distorted, often blurred, and, even when well drawn, injurious to the freshness of first impressions. Such has been the fate of most of us with regard to the Falls of Niagara. There was little accuracy in the estimates of the first observers of the cataract. Startled by an exhibition of power so novel and so grand, emotion leaped beyond the control of the judgment, and gave currency to notions regarding the water-fall which have often led to disappointment.

A record of a voyage in 1535, by a French mariner named Jacques Cartier, contains, it is said, the first printed allusion to Niagara. In 1603 the first map of the district was constructed by a Frenchman named Champlain. In 1648 the Jesuit Rageneau, in a letter to his superior at Paris, mentions Niagara as "a cataract of frightful height."[2] In the winter of 1678 and 1679 the cataract was visited by Father Hennepin, and described in a book dedicated "to the King of Great Britain." He gives a drawing of the water-fall, which shows that serious changes have taken place since his time. He describes it as "a great and prodigious cadence of water, to which the universe does not offer a parallel." The height of the fall, according to Hennepin, was more than 600 feet. "The waters," he says, "which fall from this great precipice do foam and boil in the most astonishing manner, making a noise more terrible than that of thunder. When the wind blows to the south, its frightful roaring may be heard for more than fifteen leagues." The Baron la Hontan, who visited Niagara in 1687, makes the height 800 feet. In 1721, Charlevoix, in a letter to Madame de Maintenon, after referring to the exaggerations of his predecessors, thus states the result of his own observations: "For my part, after examining it on all sides, I am inclined to think that we cannot allow it less than 140 or 150 feet"—a remarkably close estimate. At that time, viz., a hundred and fifty years ago, it had the shape of a horseshoe, and reasons will subsequently be given for holding that this

[1] A lecture before the Royal Institution, delivered April 4, 1873.

[2] From an interesting little book presented to me at Brooklyn by its author, Mr. Holly, some of these data are derived: Hennepin, Kalm, Bakewell, Lyell, and others, I have myself consulted.

has been always the form of the cataract from its origin to its present site.

As regards the noise of the cataract, Charlevoix declares the accounts of his predecessors, which, I may say, are repeated to the present hour, to be altogether extravagant. He is perfectly right. The thunders of Niagara are formidable enough to those who really seek them at the base of the Horseshoe Fall; but on the banks of the river, and particularly above the fall, its silence, rather than its noise, is surprising. This arises, in part, from the lack of resonance, the surrounding country being flat, and therefore furnishing no echoing surfaces to reënforce the shock of the water. The resonance from the surrounding rocks causes the Swiss Rouss at the Devil's Bridge, when full, to thunder more loudly than the Niagara.

On Friday, the 1st of November, 1872, just before reaching the village of Niagara Falls, I caught, from the railway-train, my first glimpse of the smoke of the cataract. Immediately after my arrival, I went with a friend to the northern end of the American Fall. It may be that my mood at the time toned down the impression produced by the first aspect of this grand cascade; but I felt nothing like disappointment, knowing, from old experience, that time and close acquaintanceship, the gradual interweaving of mind and Nature, must powerfully influence my final estimate of the scene. After dinner we crossed to Goat Island, and, turning to the right, reached the southern end of the American Fall. The river is here studded with small islands. Crossing a wooden bridge to Luna Island, and clasping a tree which grows near its edge, I looked long at the cataract, which here shoots down the precipice like an avalanche of foam. It grew in power and beauty as I gazed upon it. The channel, spanned by the wooden bridge, was deep, and the river there doubled over the edge of the precipice like the swell of a muscle, unbroken. The ledge here overhangs, the water being poured out far beyond the base of the precipice. A space, called the Cave of the Winds, is thus enclosed between the wall of rock and the cataract.

Goat Island terminates in a sheer dry precipice, which connects the American and the Horseshoe Falls. Midway between both is a wooden hut, the residence of the guide to the Cave of the Winds, and from the hut a winding staircase, called Biddle's Stair, descends to the base of the precipice. On the evening of my arrival I went down this stair, and wandered along the bottom of the cliff. One well-known factor in the formation and retreat of the cataract was immediately observed. A thick layer of limestone formed the upper portion of the cliff. This rested upon a bed of soft shale, which extended round the base of the cataract. The violent recoil of the water against this yielding substance crumbles it away, undermining the ledge above, which, unsupported, eventually breaks off, and produces the observed recession.

At the southern extremity of the Horseshoe is a promontory, formed by the doubling back of the gorge, excavated by the cataract, and into which it plunges. On the promontory stands a stone building, called the Terrapin Tower, the door of which had been nailed up because of the decay of the staircase within it. Through the kindness of Mr. Townsend, the superintendent of Goat Island, the door was opened for me. From this tower, at all hours of the day, and at some hours of the night, I watched and listened to the Horseshoe Fall. The river here is evidently much deeper than the American branch; and, instead of bursting into foam where it quits the ledge, it bends solidly over and falls in a continuous layer of the most vivid green. The tint is not uniform, but varied, long stripes of deeper hue alternating with bands of brighter color. Close to the ledge over which the water rolls, foam is generated, the light falling upon which, and flashing back from it, is sifted in its passage to and fro, and changed from white to emerald green. Heaps of superficial foam are also formed at intervals along the ledge, and immediately drawn down in long white striæ.[1] Lower down, the surface, shaken by the reaction from below, incessantly rustles into whiteness. The descent finally resolves itself into a rhythm, the water reaching the bottom of the fall in periodic gushes. Nor is the spray uniformly diffused through the air, but is wafted through it in successive veils of gauze-like texture. From all this it is evident that beauty is not absent from the Horseshoe Fall, but majesty is its chief attribute. The plunge of the water is not wild, but deliberate, vast, and fascinating. From the Terrapin Tower, the adjacent arm of the Horseshoe is seen projected against the opposite one, midway down; to the imagination, therefore, is left the picturing of the gulf into which the cataract plunges.

The delight which natural scenery produces in some minds is difficult to explain, and the conduct which it prompts can hardly be fairly criticised by those who have never experienced it. It seems to me a deduction from the completeness of the celebrated Thomas Young, that he was unable to appreciate natural scenery. "He had really," says Dean Peacock, "no taste for life in the country; he was one of those who thought that no one who was able to live in London would be content to live elsewhere." Well, Dr. Young, like Dr. Johnson, had a right to his delights; but I can understand a hesitation to accept them, high as they were, to the exclusion of

> "That o'erflowing joy which Nature yields
> To her true lovers."

To all who are of this mind, the strengthening of desire on my part to see and know Niagara Falls, as far as it is possible for them to be seen and known, will be intelligible.

[1] The direction of the wind, with reference to the course of a ship, may be inferred with accuracy from the foam-streaks on the surface of the sea.

On the first evening of my visit, I met, at the head of Biddle's Stair, the guide to the Cave of the Winds. He was in the prime of manhood—large, well built, firm and pleasant in mouth and eye. My interest in the scene stirred up his, and made him communicative. Turning to a photograph, he described, by reference to it, a feat which he had accomplished some time previously, and which had brought him almost under the green water of the Horseshoe Fall. "Can you lead me there to-morrow?" I asked. He eyed me inquiringly, weighing, perhaps, the chances of a man of light build and with gray in his whiskers in such an undertaking. "I wish," I added, "to see as much of the fall as can be seen, and where you lead I will endeavor to follow." His scrutiny relaxed into a smile, and he said, "Very well; I shall be ready for you to-morrow."

On the morrow, accordingly, I came. In the hut at the head of Biddle's Stair I stripped wholly, and redressed according to instructions—drawing on two pairs of woollen pantaloons, three woollen jackets, two pairs of socks, and a pair of felt shoes. Even if wet, my guide urged that the clothes would keep me from being chilled, and he was right. A suit and hood of yellow oil-cloth covered all. Most laudable precautions were taken by the young assistant of the guide to keep the water out, but his devices broke down immediately when severely tested.

We descended the stair; the handle of a pitchfork doing in my case the duty of an alpenstock. At the bottom my guide inquired whether we should go first to the Cave of the Winds, or to the Horseshoe, remarking that the latter would try us most. I decided to get the roughest done first, and he turned to the left over the stones. They were sharp and trying. The base of the first portion of the cataract is covered with huge bowlders, obviously the ruins of the limestone ledge above. The water does not distribute itself uniformly among these, but seeks for itself channels through which it pours torrentially. We passed some of these with wetted feet, but without difficulty. At length we came to the side of a more formidable current. My guide walked along its edge until he reached its least turbulent portion. Halting, he said, "This is our greatest difficulty; if we can cross here, we shall get far toward the Horseshoe."

He waded in. It evidently required all his strength to steady him. The water rose above his loins, and it foamed still higher. He had to search for footing, amid unseen bowlders, against which the torrent rose violently. He struggled and swayed, but he struggled successfully, and finally reached the shallower water at the other side. Stretching out his arm, he said to me, "Now come on." I looked down the torrent as it rushed to the river below, which was seething with the tumult of the cataract. De Saussure recommended the inspection of Alpine dangers with the view of making them familiar to the eye before they are encountered; and it is a wholesome custom, in places of difficulty, to put the possibility of an accident clearly before the mind, and to decide beforehand what ought to be done should the accident occur. Thus wound up in the present instance, I entered the water. Even where it was not more than knee-deep its power was manifest. As it rose around me, I sought to split the torrent by presenting a side to it; but the insecurity of the footing enabled it to grasp the loins, twist me fairly round, and bring its impetus to bear upon the back. Further struggle was impossible; and, feeling my balance hopelessly gone, I turned, flung myself toward the bank I had just quitted, and was instantly swept into shallower water.

The oil-cloth covering was a great incumbrance; it had been made for a much stouter man, and, standing upright after my submersion, my legs occupied the centres of two bags of water. My guide exhorted me to try again. Prudence was at my elbow, whispering dissuasion; but, taking every thing into account, it appeared more immoral to retreat than to proceed. Instructed by the first misadventure, I once more entered the stream. Had the alpenstock been of iron it might have helped me; but, as it was, the tendency of the water to sweep it out of my hands rendered it worse than useless. I, however, clung to it by habit. Again the torrent rose, and again I wavered; but, by keeping the left hip well against it, I remained upright, and at length grasped the hand of my leader at the other side. He laughed pleasantly. The first victory was gained, and he enjoyed it. "No traveller," he said, "was ever here before." Soon afterward, by trusting to a piece of drift-wood which seemed firm, I was again taken off my feet, but was immediately caught by a protruding rock.

We clambered over the bowlders toward the thickest spray, which soon became so weighty as to cause us to stagger under its shock. For the most part nothing could be seen; we were in the midst of bewildering tumult, lashed by the water, which sounded at times like the cracking of innumerable whips. Underneath this was the deep, resonant roar of the cataract. I tried to shield my eyes with my hands, and look upward; but the defence was useless. My guide continued to move on, but at a certain place he halted, and desired me to take shelter in his lee and observe the cataract. The spray did not come so much from the upper ledge as from the rebound of the shattered water when it struck the bottom. Hence the eyes could be protected from the blinding shock of the spray, while the line of vision to the upper ledges remained to some extent clear. On looking upward over the guide's shoulder I could see the water bending over the ledge, while the Terrapin Tower loomed fitfully through the intermittent spray-gusts. We were right under the tower. A little farther on, the cataract, after its first plunge, hit a protuberance some way down, and flew from it in a prodigious burst of spray; through this we staggered. We rounded the promontory on which the Terrapin Tower stands, and pushed, amid the wildest commotion, along the arm of the Horseshoe, until the bowlders failed us, and the cataract fell into the profound gorge of the Niagara River.

Here my guide sheltered me again, and desired me to look up; I did so, and could see, as before, the green gleam of the mighty curve sweeping over the upper ledge, and the fitful plunge of the water as the spray between us and it alternately gathered and disappeared. An eminent friend of mine often speaks to me of the mistake of those physicians who regard man's ailments as purely chemical, to be met by chemical remedies only. He contends for the psychological element of cure. By agreeable emotions, he says, nervous currents are liberated which stimulate blood, brain, and viscera. The influence rained from ladies' eyes enables my friend to thrive on dishes which would kill him if eaten alone. A sanative effect of the same order I experienced amid the spray and thunder of Niagara. Quickened by the emotions there aroused, the blood sped exultingly through the arteries, abolishing introspection, clearing the heart of all bitterness, and enabling one to think with tolerance, if not with tenderness, on the most relentless and unreasonable foe. Apart from its scientific value, and purely as a moral agent, the play, I submit, is worth the candle. My companion knew no more of me than that I enjoyed the wildness; but, as I bent in the shelter of his large frame, he said, "I should like to see you attempting to describe all this." He rightly thought it indescribable. The name of this gallant fellow was Thomas Conroy.

We returned, clambering at intervals up and down so as to catch glimpses of the most impressive portions of the cataract. We passed under ledges formed by tabular masses of limestone, and through some curious openings formed by the falling together of the summits of the rocks. At length we found ourselves beside our enemy of the morning. My guide halted for a minute or two, scanning the torrent thoughtfully. I said that, as a guide, he ought to have a rope in such a place; but he retorted that, as no traveller had ever thought of coming there, he did not see the necessity of keeping a rope. He waded in. The struggle to keep himself erect was evident enough; he swayed, but recovered himself again and again. At length he slipped, gave way, did as I had done, threw himself flat in the water toward the bank, and was swept into the shallows. Standing in the stream near its edge, he stretched his arm toward me. I retained the pitchfork handle, for it had been useful among the bowlders. By wading some way in, the staff could be made to reach him, and I proposed his seizing it. "If you are sure," he replied, "that, in case of giving way, you can maintain your grasp, then I will certainly hold you." I waded in, and stretched the staff to my companion. It was firmly grasped by both of us. Thus helped, though its onset was strong, I moved savely across the torrent. All danger ended here. We afterward roamed sociably among the torrents and bowlders below the Cave of the Winds. The rocks were covered with organic slime which could not have been walked over with bare feet, but the felt shoes effectually prevented slipping. We reached the cave and entered it, first by a wooden way carried over the bowlders, and then along a narrow ledge to the point eaten deepest into the shale. When the wind is from the south, the falling water, I am told, can be seen tranquilly from this spot; but, when we were there, a blinding hurricane of spray was whirled against us. On the evening of the same day, I went behind the water on the Canada side, which, I confess, struck me, after the experience of the morning, as an imposture.

To complete my knowledge it was necessary to see the fall from the river below it, and long negotiations were necessary to secure the means of doing so. The only boat fit for the undertaking had been laid up for the winter; but this difficulty, through the kind intervention of Mr. Townsend, was overcome. The main one was, to secure oarsmen sufficiently strong and skilful to urge the boat where I wished it to be taken. The son of the owner of the boat, a finely-built young fellow, but only twenty, and therefore not sufficiently hardened, was willing to go; and up the river I was informed there lived another man who could do any thing with the boat which strength and daring could accomplish. He came. His figure and expression of face certainly indicated extraordinary firmness and power. On Tuesday, the 5th of November, we started, each of us being clad in oil-cloth. The elder oarsman at once assumed a tone of authority over his companion, and struck immediately in among the breakers below the American Fall. He hugged the cross freshets instead of striking out into the smoother water. I asked him why he did so, and he replied that they were directed *outward* not *downward*. At times, the struggle to prevent the bow of the boat from being turned by them was very severe.

The spray was in general blinding, but at times it disappeared, and yielded noble views of the fall. The edge of the cataract is crimped by indentations which exalt its beauty. Here and there, a little below the highest ledge, a secondary one jets out; the water strikes it, and bursts from it in huge, protuberant masses of foam and spray. We passed Goat Island, came to the Horseshoe, and worked for a time along the base of it, the bowlders over which Conroy and myself had scrambled a few days previously lying between us and the base. A rock was before us, concealed and revealed at intervals, as the waves passed over it. Our leader tried to get above this rock, first on the outside of it. The water, however, here was in violent motion. The men struggled fiercely, the elder one ringing out an incessant peal of command and exhortation to the younger. As we were just clearing the rock, the bow came obliquely to the surge; the boat was turned suddenly round, and shot with astonishing rapidity down the river. The men returned to the charge, now trying to get up between the half-concealed rock and the bowlders to the left. But the torrent set in strongly through this channel. The tugging was quick and violent, but we made little way. At length seizing a rope, the principal oarsman made a desperate attempt to get upon one of the bowlders, hoping to be able to drag the boat through the channel; but it bumped so violently against the rock, that the man flung himself back, and relinquished the attempt.

We returned along the base of the American Fall, running in and out among the currents which rushed from it laterally into the river. Seen from below, the American Fall is certainly exquisitely beautiful, but it is a mere frill of adornment to its nobler neighbor the Horseshoe. At times we took to the river, from the centre of which the Horseshoe Fall appeared especially magnificent. A streak of cloud across the neck of Mont Blanc can double its apparent height, so here, the green summit of the cataract shining above the smoke of the spray appeared lifted to an extraordinary elevation. Had Hennepin and La Hontan seen the fall from this position, their estimates of the height would have been perfectly excusable.

From a point a little way below the American Fall, a ferry crosses the river in summer to the Canadian side. Below the ferry is a suspension bridge for carriages and foot-passengers, and a mile or two lower down is the railway suspension bridge. Between the ferry and the latter the river Niagara flows unruffled; but at the suspension bridge the bed steepens and the river quickens its motion. Lower down the gorge narrows, and the rapidity and turbulence increase. At the place called the "Whirlpool Rapids" I estimated the width of the river at 300 feet, an estimate confirmed by the dwellers on the spot. When it is remembered that the drainage of nearly half a continent is compressed into this space, the impetuosity of the river's escape through this gorge may be imagined. Had it not been for Mr. Bierstädt, the distinguished photographer of Niagara, I should have quitted the place without seeing these rapids; for this, and for his agreeable company to the spot, I have to thank him. From the edge of the cliff above the rapids, we descended, a little I confess to a climber's disgust, in an "elevator," because the effects are best seen from the water-level.

Two kinds of motion are here obviously active, a motion of translation, and a motion of undulation—the race of the river through its gorge, and the great waves generated by its collision with, and rebound from, the obstacles in its way. In the middle of the river the rush and tossing are most violent; at all events, the impetuous force of the individual waves is here most strikingly displayed. Vast pyramidal heaps leap incessantly from the river, some of them with such energy as to jerk their summits into the air, where they hang suspended as bundles of liquid spherules. The sun shone for a few minutes. At times, the wind, coming up the river, searched and sifted the spray, carrying away the lighter drops, and leaving the heavier ones behind. Wafted in the proper direction, rainbows appeared and disappeared fitfully in the lighter mist. In other directions the common gleam of the sunshine from the waves and their shattered crests was exquisitely beautiful. The complexity of the action was still further illustrated by the fact that in some cases, as if by the exercise of a local explosive force, the drops were shot radially from a particular centre, forming around it a kind of halo.

The first impression, and, indeed, the current explanation of these rapids is, that the central bed of the river is cumbered with large bowlders, and that the jostling, tossing, and wild leaping of the water there are due to its impact against these obstacles. This may be true to some extent, but there is another reason to be taken into account. Bowlders derived from the adjacent cliffs visibly cumber the *sides* of the river. Against these the water rises and sinks rhythmically but violently, large waves being thus produced. On the generation of each wave there is an immediate compounding of the wave-motion with the river-motion. The ridges, which in still water would proceed in circular curves round the centre of disturbance, cross the river obliquely, and the result is that, at the centre, waves commingle which have really been generated at the sides. In the first instance we had a composition of wave-motion with river-motion; here we have the coalescence of waves with waves. Where crest and furrow cross each other, the motion is annulled; where furrow and furrow cross, the river is ploughed to a greater depth; and, where crest and crest aid each other, we have that astonishing leap of the water which breaks the cohesion of the crests, and tosses them shattered into the air. From the water-level the cause of the action is not so easily seen; but from the summit of the cliff the lateral generation of the waves and their propagation to the centre are perfectly obvious. If this explanation be correct, the phenomena observed at the Whirlpool Rapids form one of the grandest illustrations of the principle of *interference*. The Nile "cataract," Mr. Huxley informs me, offers examples of the same action.

At some distance below the Whirlpool Rapids we have the celebrated whirlpool itself. Here the river makes a sudden bend to the northeast, forming nearly a right angle with its previous direction. The water strikes the concave bank with great force, and scoops it incessantly away. A vast basin has been thus formed, in which the sweep of the river prolongs itself in gyratory currents. Bodies and trees which have come over the falls are stated to circulate here for days without finding the outlet. From various points of the cliffs above, this is curiously hidden. The rush of the river into the whirlpool is obvious enough; and, though you imagine the outlet must be visible, if one existed, you cannot find it. Turning, however, round the bend of the precipice to the northeast, the outlet comes into view.

The Niagara season had ended; the chatter of sight-seers had ceased, and the scene presented itself as one of holy seclusion and beauty. I went down to the river's edge, where the weird loneliness and loveliness seemed to increase. The basin is enclosed by high and almost precipitous banks—covered, when I was there, with russet woods. A kind of mystery attaches itself to gyrating water, due perhaps to the fact that we are to some extent ignorant of the direction of its force. It is said that at certain points of the whirlpool pine-trees are sucked down, to be ejected mysteriously elsewhere. The water is of the brightest emerald-green. The gorge through which it escapes is narrow, and the motion of the river swift though silent. The surface is steeply inclined, but it is perfectly unbroken. There are no lateral waves, no ripples with their breaking bubbles to raise a murmur; while the depth is here too great to allow the inequality of the bed to ruffle the surface. Nothing can be more beautiful than this sloping, liquid mirror formed by the Niagara in sliding from the whirlpool.

The green color is, I think, correctly accounted for in the "Hours of Exercise in the Alps." In crossing the Atlantic I had frequent opportunities of testing the explanation there given. Looked properly down upon, there are portions of the ocean to which we should hardly ascribe a trace of blue; at the most a hint of indigo reaches the eye. The water, indeed, is practically *black*, and this is an indication both of its depth and its freedom from mechanically-suspended matter. In small thicknesses water is sensibly transparent to all kinds of light; but, as the thickness increases, the rays of low refrangibility are first absorbed, and after them the other rays. Where, therefore, the water is very deep and very pure, *all* the colors are absorbed, and such water ought to appear black, as no light is sent from its interior to the eye. The approximation of the Atlantic Ocean to this condition is an indication of its extreme purity.

Throw a white pebble into such water; as it sinks it becomes greener and greener, and, before it disappears, it reaches a vivid blue-green. Break such a pebble into fragments, each of these will behave like the unbroken mass; grind the pebble to powder, every particle will yield its modicum of green; and, if the particles be so fine as to remain suspended in the water, the scattered light will be a uniform green. Hence the greenness of shoal water. You go to bed with the black Atlantic around you. You rise in the morning and find it a vivid green; and you correctly infer that you are crossing the bank of Newfoundland. Such water is found charged with fine matter in a state of mechanical suspension. The light from the bottom may sometimes come into play, but it is not necessary. A storm can render the water muddy by rendering the particles too numerous and gross. Such a case occurred toward the close of my visit to Niagara. There had been rain and storm in the upper-lake regions, and the quantity of suspended matter brought down quite extinguished the fascinating green of the Horseshoe.

Nothing can be more superb than the green of the Atlantic waves when the circumstances are favorable to the exhibition of the color. As long as a wave remains unbroken, no color appears, but, when the foam just doubles over the crest like an Alpine snow-cornice, under the cornice we often see a display of the most exquisite green. It is metallic in its brilliancy. But the foam is necessary to its production. The foam is first illuminated, and it scatters the light in all directions; the light which passes through the higher portion of the wave alone reaches the eye, and gives to that portion its matchless color. The folding of the wave, producing, as it does, a series of longitudinal protuberances and furrows, which act like cylindrical lenses, introduces variations in the intensity of the light, and materially enhances its beauty.

We have now to consider the genesis and proximate destiny of the Falls of Niagara. We may open our way to this subject by a few preliminary remarks upon erosion. Time and intensity are the main factors of geologic change, and they are in a certain sense convertible. A feeble force, acting through long periods, and an intense force, acting through short ones, may produce, approximately, the same results. Here, for example, are some stones kindly lent to me by Dr. Hooker. The first examples of the kind were picked up by Mr. Hackworth on the shores of Lyell's Bay, near Wellington, in New Zealand, and described by Mr. Travers in the Transactions of the New Zealand Institute. Unacquainted with their origin, you would certainly ascribe their forms to human workmanship. They resemble flint knives and spear-heads, being apparently chiselled off into facets with as much attention to symmetry as if a tool guided by human intelligence had passed over them. But no human instrument has been brought to bear upon these stones. They have been wrought into their present shape by the wind-blown sand of Lyell's Bay. Two winds are dominant here, and they in succession urged the sand against opposite sides of the stone; every little particle of sand chipped away its infinitesimal bit of stone, and in the end sculptured these singular forms.[1]

[1] "These stones, which have a strong resemblance to works of human art, occur in great abundance, and of various sizes, from half an inch to several inches in length. A large number were exhibited, showing the various forms, which are those of wedges, knives, arrow-heads, etc., and all with sharp cutting edges.

"Mr. Travers explained that, notwithstanding their artificial appearance, these stones were formed by the cutting action of the wind-driven sand, as it passed to and fro over an exposed bowlder-bank. He gave a minute account of the manner in which the varie-

You know that the Sphinx of Egypt is nearly covered up by the sand of the desert. The neck of the Sphinx is partly cut across, not, as I am assured by Mr. Huxley, by ordinary weathering, but by the eroding action of the fine sand blown against it. In these cases Nature furnishes us with hints which may be taken advantage of in art; and this action of sand has been recently turned to extraordinary account in the United States. When in Boston, I was taken by Mr. Josiah Quincy to see the action of the *sand-blast.* A kind of hopper containing fine silicious sand was connected with a reservoir of compressed air, the pressure being variable at pleasure. The hopper ended in a long slit, from which the sand was blown. A plate of glass was placed beneath this slit, and caused to pass slowly under it; it came out perfectly depolished, with a bright opalescent glimmer, such as could only be produced by the most careful grinding. Every little particle of sand urged against the glass, having all its energy concentrated on the point of impact, formed there a little pit, the depolished surface consisting of innumerable hollows of this description. But this was not all. By protecting certain portions of the surface, and exposing others, figures and tracery of any required form could be etched upon the glass. The figures of open iron-work could be thus copied, while wire gauze placed over the glass produced a reticulated pattern. But it required no such resisting substance as iron to shelter the glass. The patterns of the finest lace could be thus reproduced, the delicate filaments of the lace itself offering a sufficient protection.

All these effects have been obtained with a simple model of the sand-blast devised for me by my assistant. A fraction of a minute suffices to etch upon glass a rich and beautiful lace pattern. Any yielding substance may be employed to protect the glass. By immediately diffusing the shock of the particle, such substances practically destroy the local erosive power. The hand can bear without inconvenience a sand-shower which would pulverize glass. Etchings executed on glass, with suitable kinds of ink, are accurately worked out by the sand-blast. In fact, within certain limits, the harder the surface, the greater is the concentration of the shock, and the more effectual is the erosion. It is not necessary that the sand should be the harder substance of the two; corundum, for example, is much harder than quartz; still, quartz-sand can not only depolish, but actually blow a hole through a plate of corundum. Nay, glass may be

ties of form are produced, and referred to the effect which the erosive action thus indicated would have on railway and other works executed on sandy tracts.

"Dr. Hector stated that, although, as a group, the specimens on the table could not well be mistaken for artificial productions, still the forms are so peculiar, and the edges, in a few of them, so perfect, that, if they were discovered associated with human works, there is no doubt that they would have been referred to the so-called 'stone period.'"—*Extracted from the Minutes of the Wellington Philosophical Society, February* 9, 1869.

depolished by the impact of fine shot; the lead in this case bruising the glass before it has time to flatten and turn its energy into heat.

And here, in passing, we may tie together one or two apparently unrelated facts. Supposing you turn on, at the lower part of this house, a cock which is fed by a pipe from a cistern at the top of the house, the column of water, from the cistern downward, is set in motion. By turning off the cock, this motion is stopped; and, when the turning off is very sudden, the pipe, if not strong, may be burst by the internal impact of the water. By distributing the turning of the cock over half a second of time, the shock and danger of rupture may be entirely avoided. We have here an example of the concentration of energy in *time*. The sand-blast illustrates the concentration of energy in *space*. The action of flint and steel is an illustration of the same principle. The heat required to generate the spark is intense, and the mechanical action, being moderate, must, to produce fire, be in the highest degree concentrated. This concentration is secured by the collision of hard substances. Calc-spar will not supply the place of flint, nor lead the place of steel, in the production of fire by collision. With the softer substances, the *total* heat produced may be greater than with the hard ones, but, to produce the spark, the heat must be intensely *localized*.

But we can go far beyond the mere depolishing of glass; indeed, I have already said that quartz-sand can wear a hole through corundum. This leads me to express my acknowledgments to General Tilghman,[1] who is the inventor of the sand-blast. To his spontaneous kindness I am indebted for these beautiful illustrations of his process. In this plate of glass you find a figure worked out to a depth of ⅜ of an inch. Here is a second plate ⅞ of an inch thick, entirely perforated. Here, again, is a circular plate of marble, nearly half an inch thick, through which open-work of the most intricate and elaborate description has been executed. It would probably take many days to perform this work by any ordinary process; with the sand-blast it was accomplished in an hour. So much for the strength of the blast; its delicacy is illustrated by this beautiful example of line-engraving, etched on glass by means of the blast.

This power of erosion, so strikingly displayed when sand is urged by air, will render you better able to conceive its action when urged by water. The erosive power of a river is vastly augmented by the solid matter carried along with it. Sand or pebbles caught in a river-

[1] The absorbent power, if I may use the phrase, exerted by the industrial arts in the United States, is forcibly illustrated by the rapid transfer of men like Mr. Tilghman from the life of the soldier to that of the civilian. General McClellan, now a civil engineer, whom I had the honor of frequently meeting in New York, is a most eminent example of the same kind. At the end of the war, indeed, a million and a half of men were thus drawn, in an astonishingly short time, from military to civil life. It is obvious that a nation with these tendencies can have no desire for war.

vortex can wear away the hardest rock; "pot-holes" and deep cylindrical shafts being thus produced. An extraordinary instance of this kind of erosion is to be seen in the Val Tournanche, above the village of this name. The gorge at Handeck has been thus cut out. Such water-falls were once frequent in the valleys of Switzerland; for hardly any valley is without one or more transverse barriers of resisting material, over which the river flowing through the valley once fell as a cataract. Near Pontresina, in the Engadine, there is such a case, the hard gneiss being now worn away to form a gorge through which the river from the Morteratsch Glacier rushes. The barrier of the Kirchet, above Meyringen, is also a case in point. Behind it was a lake, derived from the glacier of the Aar, and over the barrier the lake poured its excess of water. Here the rock, being limestone, was in great part dissolved, but, added to this, we had the action of the solid particles carried along by the water, each of which, as it struck the rock, chipped it away like the particles of the sand-blast. Thus, by solution and mechanical erosion, the great chasm of the Fensteraarschlucht was formed. It is demonstrable that the water which flows at the bottoms of such deep fissures once flowed at the level of what is now their edges, and tumbled down the lower faces of the barriers. Almost every valley in Switzerland furnishes examples of this kind; the untenable hypothesis of earthquakes, once so readily resorted to in accounting for these gorges, being now, for the most part, abandoned. To produce the cañons of Western America, no other cause is needed than the integration of effects individually infinitesimal.

And now we come to Niagara. Soon after Europeans had taken possession of the country, the conviction appears to have arisen that the deep channel of the river Niagara below the Falls had been excavated by the cataract. In Mr. Bakewell's "Introduction to Geology," the prevalence of this belief has been referred to: it is expressed thus by Prof. Joseph Henry in the Transactions of the Albany Institute: "In viewing the position of the Falls, and the features of the country round, it is impossible not to be impressed with the idea that this great natural race-way has been formed by the continued action of the irresistible Niagara, and that the Falls, beginning at Lewiston, have, in the course of ages, worn back the rocky strata to their present site."[1] The same view is advocated by Mr. Hall, by Sir Charles Lyell, by M. Agassiz, by Prof. Ramsay—indeed, by almost all of those who have inspected the place.

A connected image of the origin and progress of the fall is easily obtained. Walking northward from the village of Niagara Falls by the side of the river, we have, to our left, the deep and comparatively narrow gorge through which the Niagara flows. The bounding cliffs of this gorge are from 300 to 350 feet high. We reach the whirlpool, trend to the northeast, and, after a little time, gradually resume our

[1] Quoted by Bakewell.

northward course. Finally, at about seven miles from the present Falls, we come to the edge of a declivity which informs us that we have been hitherto walking on table-land. At some hundreds of feet below us is a comparatively level plain, which stretches to Lake Ontario. The declivity marks the end of the precipitous gorge of the Niagara. Here the river escapes from its steep, mural boundaries, and, in a widened bed, pursues its way to the lake, which finally receives its waters.

The fact that, in historic times, even within the memory of man, the fall has sensibly receded, prompts the question, How far has this recession gone? At what point did the ledge which thus continually creeps backward begin its retrograde course? To minds disciplined in such researches the answer has been, and will be, at the precipitous declivity which crossed the Niagara from Lewiston, on the American, to Queenstown, on the Canadian side. Over this transverse barrier the united affluents of all the upper lakes once poured their waters, and here the work of erosion began. The dam, moreover, was demonstrably of sufficient height to cause the river above it to submerge Goat Island; and this would perfectly account for the finding by Mr. Hall, Sir Charles Lyell, and others, in the sand and gravel of the island, the same fluviatile shells as are now found in the Niagara River higher up. It would also account for those deposits along the sides of the river, the discovery of which enabled Lyell, Hall, and Ramsay, to reduce to demonstration the popular belief that the Niagara once flowed through a shallow valley.

The physics of the problem of excavation, which I made clear to my mind before quitting Niagara, are revealed by a close inspection of the present Horseshoe Fall. Here we see evidently that the greatest weight of water bends over the very apex of the Horseshoe. In a passage in his excellent chapter on Niagara Falls, Mr. Hall alludes to this fact. Here we have the most copious and the most violent whirling of the shattered liquid; here the most powerful eddies recoil against the shale. From this portion of the fall, indeed, the spray sometimes rises, without solution of continuity, to the region of clouds, becoming gradually more attenuated, and passing finally through the condition of true cloud into invisible vapor, which is sometimes reprecipitated higher up. All the phenomena point distinctly to the centre of the river as the place of greatest mechanical energy, and from the centre the vigor of the fall gradually dies away toward the sides. The horseshoe form, with the concavity facing downward, is an obvious and necessary consequence of this action. Right along the middle of the river the apex of the curve pushes its way backward, cutting along the centre a deep and comparatively narrow groove, and draining the sides as it passes them.[1] Hence the remarkable discrepancy between the widths of the Niagara above and below the Horseshoe. All along

[1] In the discourse this action was illustrated by a model.

its course, from Lewiston Heights to its present position, the form of the fall was probably that of a horseshoe; for this is merely the expression of the greater depth, and consequently greater excavating power, of the centre of the river. The gorge, moreover, varies in width as the depth of the centre of the ancient river varied, being narrowest where that depth was greatest.

The vast comparative erosive energy of the Horseshoe Fall comes strikingly into view when it and the American Fall are compared together. The American branch of the upper river is cut at a right angle by the gorge of the Niagara. Here the Horseshoe Fall was the real excavator. It cut the rock, and formed the precipice over which the American Fall tumbles. But, since its formation, the erosive action of the American Fall has been almost *nil*, while the Horseshoe has cut its way for 500 yards across the end of Goat Island, and is now doubling back to excavate a channel parallel to the length of the island. This point, I have just learned, has not escaped the acute observation of Prof. Ramsay.[1] The river above the fall bends, and the Horseshoe immediately accommodates itself to the bending, following implicitly the direction of the deepest water in the upper stream. The flexibility of the gorge, if I may use the term, is determined by the flexibility of the river-channel above it. Were the Niagara above the fall far more sinuous than it is, the gorge would obediently follow its sinuosities. Once suggested, no doubt geographers will be able to point out many examples of this action. The Zambesi is thought to present a great difficulty to the erosion theory, because of the sinuosity of the chasm below the Victoria Falls. But, had the river been examined before the formation of this sinuous channel, the present zigzag course of the gorge below the fall could, I am persuaded, have been predicted, while the sounding of the present river would enable us to predict the course to be pursued by the erosion in the future.

But, not only has the Niagara River cut the gorge, it has carried away the chips of its own workshop. The shale being probably crumbled, is easily carried away. But at the base of the fall we find the huge bowlders already described, and by some means or other these are removed down the river. The ice which fills the gorge in winter, and which grapples with the bowlders, has been regarded as the transporting agent. Probably it is so to some extent. But erosion acts without ceasing on the abutting points of the bowlders, thus withdrawing their support, and urging them gradually down the river. Solution also does its portion of the work. That solid matter is carried down is proved by the difference of depth between the Niagara River and Lake Ontario, where the river enters it. The depth falls

[1] His words are: "Where the body of water is small in the American Fall, the edge has only receded a few yards (where most eroded) during the time that the Canadian Fall has receded from the north corner of Goat Island to the innermost curve of the Horseshoe Fall."—*Quarterly Journal of the Geological Society*, May, 1859.

from 72 feet to 20 feet, in consequence of the deposition of solid matter caused by the diminished motion of the river.[1]

In conclusion, we may say a word regarding the proximate future of Niagara. At the date of excavation assigned to it by Sir Charles Lyell, namely, a foot a year, five thousand years will carry the Horseshoe Fall far higher than Goat Island. As the gorge recedes, it will drain, as it has hitherto done, the banks right and left of it, thus leaving a nearly level terrace between Goat Island and the edge of the gorge. Higher up it will totally drain the American branch of the river, the channel of which in due time will become cultivable land. The American Fall will then be transformed into a dry precipice, forming a simple continuation of the cliffy boundary of the Niagara. At the place occupied by the fall at this moment we shall have the gorge enclosing a right angle, a second whirlpool being the consequence of this. To those who visit Niagara five millenniums hence, I leave the verification of this prediction; for my own part, I have a profound persuasion that it will prove literally true.

STATE GEOLOGICAL SURVEYS.

By Prof. ALBERT R. LEEDS,

OF THE STEVENS INSTITUTE OF TECHNOLOGY.

A STRENUOUS effort is being made at the present time to reorganize the Geological Survey of Pennsylvania. It promises to be successful. The legislators of that State, in voting upon the measure, will be mainly influenced by considerations relating to the pecuniary value of a geological survey in locating beds of coal, building-materials, and ores. But the educated public will desire to know, in addition to these matters, what influence such a geological survey will have upon the intellectual activity of the community at large, and how great an amount of scientific bustle it will create in the museums and laboratories of institutions of learning.

A very satisfactory answer can be given to the first of these queries, after reviewing the scientific periodicals and journals of learned societies in this country, during the last half-century. It will be seen that the desultory descriptions of plants, birds, and the external characters of minerals, which constituted a large portion of the scientific literature at the beginning of this period, gave place to laborious analyses, and to elaborate articles on geological phenomena. Many of the most valuable contributions to science during this epoch consisted in reports of the geological surveys then in progress, or in-

[1] Near the mouth of the gorge at Queenstown, the depth, according to the Admiralty Chart, is 180 feet; well within the gorge it is 132 feet.

vestigations connected with and growing out of them. Much of the best talent of the time was engaged upon these stupendous labors, and around the eminent chiefs were gathered bands of enterprising students, whose methods of scientific work were formed beneath the eyes of masters. The assistants of earlier surveys are the directors of those now in progress, and the crude sketches of former times are replaced by huge volumes filled with exhaustive details and magnificent generalizations.

Great as has been the work accomplished, the question may nevertheless be asked, whether the State geological surveys are, or have been, organized in such a manner as to exert the greatest possible influence upon the scientific progress of their respective States. As heretofore constituted, they have consisted of a director and a number of assistants, who have drawn their salaries and prosecuted their labors until the State appropriations have been exhausted. In some instances the work of the assistants has been appropriated by the director in such a manner that the geological survey has appeared to the public to be entirely represented in the person of its presiding officer. Granting that this officer is better qualified than any one else, it is evident, nevertheless, that a geological bureau, thus constituted, must reject a large part of the available talent of a State. Still worse, by taking possession of the field, and by closing the columns of the report to all but the paid officials of the survey, many whose labors might be of great value are rendered indifferent or hostile to the work. A bureau framed in the manner above described is proper enough in the survey of Territories still largely occupied by Indians, but it is by no means suited to the condition or needs of a densely-populated State. When a dozen flourishing colleges exist within the boundaries of a State, is it well that a general geological survey should be made in such a manner as to apportion little if any of its work specifically to them? A survey so constituted tends to encourage a disposition, unfortunately only too prevalent among our collegiate professors, to regard their entire duty as performed when the labor of teaching is accomplished. A few days ago an eminent civil engineer, who in his moments of *leisure* has collected one of the finest cabinets of minerals in this country and has made himself a practised mineralogist, complained that, after twenty years of disappointments, he had grown wearied of sending doubtful specimens to professors in colleges for determination, and of receiving no answers after the lapse of many months. As a final resort, he has determined new species himself, and had the chemical analysis performed by a hard-worked chemist in a manufacturing establishment. A large part of the work of a geological survey should be assigned to the colleges in a State, and should be voluntarily performed by their professors. Every State from Maine to Florida should be divided up into collegiate districts, the scientific development of which should be more immediately under the care of the particular college in the midst of each. There is no reason why a system of joint effort, which from time immemorial has accomplished such wonderful things for religion and social order, should not be equally efficacious in scientific matters. A feeling of honorable pride should induce the officers and students of each institution to illustrate the flora and fauna, the mineralogy and geology of its collegiate district, more perfectly than any stranger could. The amount of intellectual labor which is utilized, and the number of valuable data collected each year, form but a small proportion of what is annually lost to the community through lack of organized effort. In a tersely-written letter to the Governor of Pennsylvania, urging the need of a new survey, Prof. Lesley says: "A most important function of a geological survey is, to *preserve* knowledge *for future use.* Science is cumulative. It makes slow and painful advances. It is obliged to collect an abundance of facts before it comes to true conclusions. Pennsylvania has lost enormously during the last twenty years by having no bureau of statistics, no corps of observation and publication, to observe and preserve, collate and relate, the facts of its geology and mineralogy, as they have successively made their appearance. No commonwealth can afford to be without such an apparatus for preserving from loss and forgetfulness the discoveries and investigations of private persons, even for one single year of its existence. Thousands of most valuable facts have been lost to us, during an interval, which cannot be recovered. How many openings on coal-veins are now covered up, no one being able to give any reliable information about them. Twenty thousand oil-borings have been made, and not one hundred of them are on record, if discoverable. Hundreds of gangways have been driven and abandoned, and cannot now be studied, many of which would disclose the nature of faults and disturbances which affect neighboring properties, and overlying and underlying beds not yet worked, where certain knowledge is preserved to govern the future mining-engineer in his plans for getting at the mineral. He must work as completely in the dark as if his knowledge had never been got, and often paid for at a ruinous expense. The sooner a geological survey is established, the better for the *future* interests of the State, as well as for its present necessities." At the height of the oil-fever in Pennsylvania, appreciating the wonderful opportunity which the sinking of innumerable wells afforded for obtaining complete geological sections of a vast area, I spent a long time in endeavoring to obtain from the superintendents engaged in boring, by personally visiting hundreds of wells in succession, the records of their work, and specimens of the penetrated strata. Printed circulars, asking for copies of such records in the interests of science, were sent to the secretary of every oil-company within our knowledge. Partly from the disgusting greed which possessed the oil-speculators to the exclusion of every higher feeling, and partly from an insane dread that the possession of such knowledge would bestow an infallible talisman for striking oil, these attempts were in but half a dozen instances successful. Is it wonderful that such crass ignorance should have entailed ruin upon thousands? Nothing but the publication of exhaustive geological reports, continued year after year, and printed both in full and summarized into short popular forms, can save the community at large from the repetition of similar follies. One single mining-fever costs the State more than all the appropriations needed to discover and universally diffuse the truths of geology. The ignorance spoken of above finds a parallel only in the methods which were pursued in treating the crude petroleum after it had been sent to market. The director of the principal chemical manufactory in Western Pennsylvania informed the writer that they first attempted to refine crude petroleum by throwing hundreds of pounds of bergamot and other perfumes into it, to *take away the smell.* If the reader says that this story is incredible, I can only repeat, "Yes, it is incredible."

It may be urged that few men are placed in such positions, or provided with such appliances, or possessed of sufficient leisure, to contribute any thing of value to the general stock of geological knowledge. But there are hundreds who would shrink from publishing a lengthy article or reading a paper before a learned body, and yet are acute reasoners and accurate observers, and whose abilities could be made available by a good system of collecting and collating their fragmentary labors. I have met many school-teachers and pastors in Switzerland whose parochial duties confined them to obscure valleys among the mountains, and who still had found time to collect the fossils, plants, and minerals, of their poverty-stricken hamlets, and to make careful maps of the rock-strata. They did so for two reasons: In the first place, the topographical map of General Dufour, on a scale of 1 to 100,000, previously accomplished by national aid, rendered it possible for them to locate their observations of strata, etc., with precision; and, secondly, because their contributions were utilized by the professors at Zurich, Bern, Geneva, and elsewhere, and incorporated in their published geological reports. A State survey, so organized as to make every intelligent school-teacher, every country-surveyor, every civil and mining engineer, chemist, amateur or collector, one of its working corps, would, we believe, do the work better, more cheaply, and with vastly more benefit to the material and intellectual prosperity of the State, than any present organization. This would be a school of science indeed, unincumbered by the dead weight of expensive school-buildings, whose laboratory and museum would cover every square foot of the State's surface.

NATURAL SELECTION IN POLITICS.

By Prof. D. H. WHEELER.

WHATEVER may become of Darwin's theory of natural selection, its worst foes must at last concede it the rare honor of being reckoned the most fertile hypothesis ever proclaimed. It has created a library of books on species, selection, and evolution, and it enters more or less into most attempts at serious writing. It was to be expected that it should turn up in politics; but we were hardly prepared for so brave an entry on that field as it makes in Bagehot's "Physics and Politics."

It is refreshing to know that Darwinism puts a more cheerful aspect upon physics in the social life of man than has been given to it by Draper and Buckle.

To Mr. Bagehot, the principle of natural selection applied to politics suggests the hopeful and beneficent side of law; Dr. Draper's books were preachments upon its awful and relentless aspects.

There is a valuable truth in natural selection applied to politics; for it is conceded that history shows us a struggle of races, and we who survive are ready enough to believe that the strongest survive because they are the best.

The earlier attempts to put physical forces into their place in man's social institutions, claimed a monopoly for them. The Gulf Stream wrote "Paradise Lost" and Newton's "Principia." The new attempt to trace these lines of law seems to promise success by leaving a little for Newton and Milton to do.

Physics work in harmony with morals. Morality is not a base and ragged accident, nor is it a fated product of temperature; it has relations to the weather, but the most important of these is its power to make, through industry and thought, a pleasant summer in an ice-bound city, and a grateful coolness in the torrid zone.

The moralists are fertile in all forms of social power; that is an old truth, too stubborn to be talked down. Religion has value everywhere, even in making fighters. God-fearing armies are hard to beat; and a man with an honest faith in him is as ugly a customer to face in fight as thirty degrees below zero. I hope nobody supposes that politics are without law. I know nothing so absurd as to believe in God and deny law to history, unless it be to be atheist and deny it. In truth, all of us shiver a little when we remember that God is just, or take account of the consequences that attend our public errors.

But the value of a truth is generally to be measured by its relation to hope. The best conquer, the best live; what an inspiration to courageous effort to be the best nation!

All the moralities, decencies, cultures, worships, lift up, and strengthen, and vitalize a people; and the purer they are, the more they are worth as factors of nationality.

It is worth while to try to be decent, to reform bad habits, and fortify exposed places in our public life; for the best is the longest-lived.

This is not very new; a good deal of such preaching was wasted upon the Jews; but, after being sickened upon the doctrine that a fall of temperature produces a given number of suicides, and that morals have no influence in civilization, it is worth the cost of listening to a sermon, to get back again, under a disciple of Darwin, to the old truth, that it is well with the good, and ill with the evil, evermore on the earth.

The hopeful aspect given to *change* in national life by Darwinian Politics deserves special notice, and seems timely.

We are all afraid to change—born conservatives; and we all *want* something changed—born radicals; and we *do* change. All human life varies incessantly; the new generation sees life in new aspects, and rejoices in other colors. The variation comes in constantly; and it is our safety. Our inborn conservatism would kill us off if the variation did not help our inborn radicalism in the else unequal struggle. *That which is*, like the bird in the hand, is worth two reforms in the bush, for a contest. In short, nations grow, progress, thrive, through the law of variation from inheritance.

"One of the greatest pains to human nature is the pain of a new idea;" the consolation is, that only in pain does progress get birth, and that the things born are, on the whole, like the babies of any year, a little stronger and better than the things which die to give them room. Nor is this so because the moon is not made of green cheese, but because a beneficent law underlies human existence. The exceptions are numerous; so too are the small graves at Rose Hill, and yet there are more men on the earth, on the whole, happier than their ancestors, than there were fifty years ago. We must change; it is our cowardice or indolence that makes change a danger. The law deals generously with virtue and strength.

It is curious to mark how slowly we learn some of these simple lessons. A century ago, we respected, envied, the noble savage. The contemptible creature was semi-divine to first-rate poets and statesmen. They bewailed society, and longed for nakedness in the woods.

The same men knew that one Roman soldier had outmatched fifty semi-barbarians in every struggle, and that noble savages fell into the toils of the meanest civilized men in the slave-trade.

Civilization is strength and happiness. Miss Fragilla may not get all the new bonnets she wants; but that pain is easier borne than the "sound belashing" her ancestor got at her age, two centuries ago. She may not be all we could wish, but no young man of our blood would pass her by for a Choctaw princess.

The function of liberty in politics deeply interests us. Its power to promote healthful change is obvious. It is really liberty, with its discussion, its free thinking, and free speaking, that makes good politics. Cæsarism is a thief, robbing free times of their ideas and social results. It can live just as long as the loot holds out; but, when the stock on hand is exhausted, free men must be set to producing a new crop.—*The Northwestern Review.*

BARON LIEBIG.

JUSTUS VON LIEBIG, the famous German chemist, who died at Munich, April 18th, was born at Darmstadt, May 12, 1803. Having graduated from the gymnasium of his native place at the age of sixteen, his taste for the study of natural science led him first to accept a situation in an apothecary's shop, where he expected to have abundant opportunity for experiment and research.

After six months' service in the apothecary's shop, Liebig set out for the University of Bonn, where he studied for a while, and then went to Erlangen. At the latter university he attracted notice by the zeal with which he devoted himself to the study of chemistry, and he received from the Grand-duke of Hesse a "travelling stipend," which enabled him to spend two years (1822–'24) in Paris. There he had the advantage of association with Alexander von Humboldt, Gay-Lussac, and other eminent scientists. During his stay in Paris he read before the Academy of Sciences a paper on "Fulminic Acid" which at once stamped him as an able chemist. He was then only twenty-one years of age. In 1824 he was, through the influence of Humboldt, appointed Adjunct Professor of Chemistry in the University of Giessen, and two years later he succeeded to the full dignity of professor. The laboratory which he established at Giessen was the best-appointed school of chemistry in Germany, and thither flocked students from all parts of Europe, but especially from England, and also from this country. Leipsic and Göttingen set up chemical laboratories on Liebig's model, and the Giessen school became a kind of scientific focus, a centre of discovery, whose influence was felt everywhere.

Prof. Liebig visited England in 1838, attending a meeting of the British Association for the Advancement of Science. He there brought forward the discovery made by his associate, Wöhler, of a process for obtaining urea artificially. This announcement of the first successful step toward the synthesis of compounds in the laboratory, which had been supposed producible only under the influence of the mysterious forces of life, was received by the Association with profound interest. At the urgent request of the Association he wrote

PROFESSOR LIEBIG.

his work on "Organic Chemistry, in its Application to Agriculture" (Brunswick, 1840), which was translated into most European languages, and had an enormous circulation both in Europe and America. In 1845 he received from his sovereign the honor of an hereditary barony. Seven years later, in 1852, he accepted the position of Professor of Chemistry in the University of Munich, and director of the chemical laboratory of that city.

His principal works, besides those already mentioned, are: "Animal Chemistry, or Chemistry in its Applications to Physiology and Pathology" (1842); and "Familiar Letters" (1844), which brought his views on applied chemistry before a very wide public, in a style so simple and popular that practical agriculturists could understand and profit by the instruction there conveyed.

In 1848 he commenced the publication of his "*Annalen*," or, "Annual Report of the Progress of Chemical Science." He published his "Researches on the Chemistry of Food" in 1849. His "Dictionary of Chemistry," in which he had the assistance of other writers, appeared in parts between 1837 and 1851.

In estimating the relation of Baron Liebig to the thought of his age, we are not to regard him as simply a chemist; he was much more—he was, in its broadest sense, a philosophical chemist, a man of ideas. Since the death of Berzelius, no man has appeared who had the weight of universal authority in chemical science. The subject has developed into such vastness of detail, that men can only become great by limiting themselves to special branches of it. Liebig devoted himself to organic chemistry, and even here there are other men who have probably surpassed him in the number and importance of their immediate contributions to the science. Yet, since Berzelius closed his career, no *savant* has appeared in the chemical field who has achieved so brilliant and conspicuous a position as Liebig.

He had in an eminent degree the traits of a successful pioneer in the world of thought. He was a man of impulse, sympathy, and enthusiasm, as well as of intellect. He could not give his life to simple, quiet laboratory investigation, content to make a few additions to the stock of scientific truth. Although trained to the strict methods of investigation, and competent to bend his energies to specific research, yet his manly interest in his fellow-beings, and the welfare and progress of society, determined the course of his studies, and led him constantly to the development of large practical results. When he began with organic chemistry, it was in its infancy, and chiefly confined to the production of a few organic compounds by laboratory decomposition. As for the chemical interpretation of the living organism, it was hardly thought of. The mystery of the vital forces reigned supreme, and barred the way to true inductive investigation. So also with agricultural chemistry. Davy had originated the name early in the century, and presented some of its elementary facts; but they did not reach to practical results, and amounted to nothing in their influence upon the public. The work of Liebig was nothing less than to erect both these sciences into recognized branches of study, to direct the scientific thought of his age to these fields of inquiry, and to arouse the interest of the public in their practical applications; and this great work it is his lasting honor to have accomplished. That he should have committed errors, was inevitable. The first bold original speculations upon complex subjects cannot fail to be always imperfect. And, besides, that order of temperament which fitted him to be a reformer and a leader, and to stimulate and urge on other men, was favorable to rashness of generalization and a sanguine anticipation of conclusions. And yet Liebig's leading doctrines, to whatever degree requiring modification, were steps in the right direction of investigation; while their amendment and revision have made the reputations of other men.

Prof. Liebig's name will always be intimately and honorably associated with the rise of biological science in the nineteenth century. He stands at the beginning of one of the great epochs of knowledge, to which his genius has assisted to give development and direction, and he illustrates in an eminent degree that highest trait of modern character—devotion to scientific truth to the end of a large and noble utility.

It remains to be stated that Prof. Liebig entertained large and liberal political views. Although working under the European system with great success, ennobled by it, and appreciating its advantages, he nevertheless condemned its repressions and interferences, and looked beyond the ocean for the realization of his hopes and ideas. He was an enthusiast in regard to America, where he had many more readers than in any other country, and he expected great things from freedom, intelligence, and active enterprise in the United States. He even entertained serious notions of taking up his residence in our country. Like Agassiz, he saw that there were great possibilities for the future of science on this continent, and he indulged the idea, which was much more than a fancy, of establishing a great agricultural institution in one of the States. He would have been welcome here with a cordiality beyond his anticipation; for he was not only universally known and highly respected, but the most numerous class of the community—the agriculturists—recognized him as benefactor.

CORRESPONDENCE.

THE QUESTION OF COMPULSORY ATTENDANCE ON SCHOLASTIC EXERCISES IN COLLEGES.

To the Editor of the Popular Science Monthly:

THE press has recently occupied itself to an unusual degree with matters which concern our system of higher education; and a point on which the widest diversity of views has been expressed, and on which the argument on both sides has been maintained with the greatest ability and earnestness, is the question whether mental training is a process which can only be successfully conducted by assuming that its subjects will not in general receive it voluntarily, and whether, therefore, it is or is not necessary to proceed upon the plan of coercing them to their own good. This discussion originated in an intimation thrown out by President Eliot, of Harvard University, in his last annual report, to the effect that it might possibly be thought expedient in that institution hereafter to abolish the rules which make the attendance of students upon scholastic exercises compulsory, holding them, nevertheless, to rigorous examination upon the subjects taught, and conferring degrees in arts only upon satisfactory evidence of proficiency. This suggestion encountered a prompt and vigorous response and expostulation from the Rev. President McCosh, of Princeton, in a communication addressed, in January last, to the *New-York Evening Post.* Other writers took up the argument at greater or less length on both sides of the controversy; but nowhere has there appeared a more able or conclusive vindication of the wisdom of the principle involved in President Eliot's suggestion than that which was put forth in the March number of THE POPULAR SCIENCE MONTHLY. I cannot but thank you for your bold and free treatment of a subject in regard to which prescriptive usage, and the bias in the public mind which long prescription always carries with it, are against you; but which concerns in a very high degree the influence of our systems of education on the formation of the moral no less than the intellectual character of the youth who are subjected to it.

Immediately on the appearance of the article of Dr. McCosh, it was my design to offer a slight contribution to the literature of this subject, founded on my own personal observation of different educational methods during a thirty years' connection with the administration of colleges; but, owing to unforeseen interruptions, my labor remained unfinished on my hands until the favorable moment had passed by. My attention has been recently drawn to the subject again by the publication (also in the *Evening Post*) of a letter from Prof. Venable, Dean of the Faculty of the University of Virginia, describing the educational system of that institution, of which compulsory attendance is an essential feature, but referring in respectful terms to the plan proposed by President Eliot. This letter is presented by the *Post* as one of unusual importance and interest; yet it adds nothing to what has been universally known of the Virginia system for the past forty years, although it sets forth the leading features of this system with clearness and conciseness. In commending it, I understand the *Post* to be once more commending, though indirectly, the compulsory system; and this brings back to me my nearly-forgotten purpose above referred to, to have my word in this matter also.

I will commence, therefore, by remarking that all that Dr. McCosh has said, or that anybody may say, as to the importance of regular drill to the efficiency of any system of mental discipline, will be readily admitted by every experienced educator of youth. Whether, as that learned gentleman assumes, the undergraduate student is to be regarded as being too immature to be intrusted with a freedom which he may possibly abuse, or whether, with President Eliot, we suppose that he is as likely to attend to his collegiate exercises from a just appreciation of their value to himself, and a proper sense of duty, as through any species of coercion, in either case there can be no doubt that this regularity of attendance is of indispensable importance, and that, in one way or another, it must be secured. It is supposed by Dr. McCosh that Harvard University may have been influenced in her views as to this subject by the presumed usages of foreign institutions of similar grade, or by the known practice of the professional schools of our own country; and, in regard to the colleges of Great Britain and Ireland, he hastens to correct the impression, if it exists, that attendance upon scholastic exercises is not made compulsory in them. It seems to me, nevertheless, to be unnecessary to go beyond the reason assigned by President Eliot himself as indicating the expediency of the change, in order to discover his motive for proposing it. This reason is, that the average age of the undergraduate students in Harvard University (and it may be added in all our colleges at present—at least in all those of the Atlantic States) is three or four years more advanced than it was in the earlier part of this century. Dr. McCosh admits the truth of this statement. He does not even seem to deprecate the fact that mature young men seek to avail themselves of the educational advantages which colleges offer. But he hardly attempts to disguise his conviction that the college was not designed for this class of students, nor that their actual predominance in it in numbers is evidence to him that it has been perverted from the original object of its institution. This is apparent from his remark that, "if there be a diminution in the number of young men attending colleges in relation to the population, it is very much owing to the circumstance that certain of the colleges have been practically raising the age of entrance, so as to prevent persons from entering upon their professional business until some of the best years of their life are spent." In his view, therefore, the existing state of things is an evil, and the blame of it is directly chargeable upon the colleges themselves. I do not, I confess, find the evidence to sustain this view of the case. The colleges have not raised the age of entrance by legislation. The minimum age in Columbia College is fifteen years. In Yale College it is fourteen, as it has been for the past half-century. In Harvard University there is no minimum at all. If there is any mode of "practically" raising the standard except by arbitrarily rejecting the younger class of applicants, notwithstanding that, by the published regulations, they are legally admissible, it does not occur to me to conjecture what it can be; yet this is not a practice which I have ever heard imputed to any American college. But it may be said that the colleges have brought the observed result to pass by increasing the severity of the entrance tests. This hypothesis can certainly not be sustained, so far, at least, as the classics are concerned (and it is here that the great labor of preparation lies), if we take as our guide the published entrance conditions. As a rule, the reverse is even the case, the amount exacted, measured by quantity if not by quality, being materially less than it was fifty years ago. Some little addition has been made to the amount of exaction in the mathematics, but not enough to make it difficult for a lad to prepare himself for college as early as fourteen, or earlier. To these statements, Harvard College may possibly present an exception, but the increased entrance exactions there have not been in operation long enough to have had any influence in producing the phenomenon in question. If it is a fact, therefore, that the average age of undergraduate students has risen—and I believe there can be no doubt about that—it is a fact which is not imputable to the colleges, nor one which they could control if they would; unless, indeed, instead of legislating about minimum ages, they should think proper to establish a *maximum* age, above which no applicant should be admitted, and should place this low enough to exclude every individual who has passed the years of boyhood. Such a measure would probably meet with few advocates. If it were important that we should explain the remarkable fact above mentioned, it would be quite sufficient to point to the immense improvement which has taken place within the century in the training-schools of grade inferior to the colleges—schools admirably and precisely fitted to the wants of boys of tender age, and armed with a coercive power to hold them to their tasks tenfold as great as any college possesses, or can possess. For such striplings, it is well that they are at school, and that they are not in college; and to an intuitive perception of this truth on the part of parents it is unquestionably owing that so many remain there.

However this may be, we must take the facts as we find them, whether we would have them so or not, since it does not appear that we can very well make them other than they are. What is true in the present is likely to be permanently true in the future, viz., that the average age of undergraduate students in American colleges is, and will be, several years more advanced than it was three-quarters of a century ago, and even much more recently. And this important truth implies a very material change in the character of the student-body —a change marked by a large advance in maturity of judgment, an increased power of self-control, and a sensible diminution of the levity and volatility which distinguish the period of boyhood. To place such a community of young men under a system of restraints in nowise different from that which was originally devised for boys but a step removed from childhood, is to check the development of character in the direction of manly sentiment which should accompany this age, by tempting or compelling the student to govern his conduct not in accordance with the principles of propriety or right, but in obedience to an arbitrary, sometimes, in his judgment, an unreasonable, and often to his belief a needlessly oppressive rule.

The hope which President Eliot thinks it not unreasonable to entertain in regard to Harvard College, viz., "that it will soon get entirely rid of a certain school-boy spirit," which used to prevail there, but of which the traces are continually growing less, is a hope in which many similar institutions, with good reason, participate. It is a hope of which every judicious educator will do all that lies in his power to promote the fulfilment. The most unnecessary of the evils with which our colleges are at present afflicted are, those that grow out of such traces as still linger of this frivolous spirit. And if the rigorous rules which subject mature young men to a severe account of the disposition made of every moment of their time, or which place them under an irritating and annoying surveillance, are necessary (as it must be presumed they are supposed to be, or they would not be maintained), to assure their proper mental training, then certainly it is much to be lamented that these same necessary rules should be as prejudicial to their moral culture as they are said to be healthful to their mental. Is it not time, then, that we should begin to consider whether there are not influences capable of being brought to bear upon the undergraduate youth of our colleges, which will prove nearly, if not absolutely, as effectual in securing their regular attendance upon their scholastic exercises as any system of pains and penalties can be? Does the abandonment of the system of positive coercion involve necessarily the disastrous consequences apprehended by Dr. McCosh, of a neglect of faithful daily effort, and an attempt to satisfy the tests of proficiency imposed by the academic authorities, by means of a pernicious periodical cramming?

These are questions in regard to which no general agreement is likely to be reached by mere discussion. They are matters of opinion; and, when opinions differ in regard to what is likely to happen in hypothetical cases, it is generally true that the advocates of opposing views are more likely to be confirmed by argument in their original convictions, than converted to those of their adversaries. The only source from which, in matters of this kind, conclusions can be drawn which shall admit of no controversy, is actual experience; and thus far the results of experience have not been adduced by any of the parties to this discussion. President Eliot puts forward his proposed measure, not in the tone of confidence in which one speaks of a thing which has been tried and found to work well; but rather apparently as a feeler, for the purpose of trying the temper of the public mind, and ascertaining whether that is likely to tolerate so bold an experiment at Harvard; and Dr. McCosh trembles at the very thought of such an experiment in such an institution, being quite certain in advance that it must end in ignominious failure, and being apprehensive that the disastrous consequences which must follow will be felt in all the other colleges of the land. And yet, after all, this is not entirely a question of possibilities or probabilities. The experiment has been tried already, and tried until it is no longer an experiment. It has been tried at least long enough to prove that it is not surrounded by any of the dangers which seem so formidable to the distinguished president of Princeton, and that it is truly attended by all the advantageous consequences which are anticipated from it by the enlightened and progressive president of Harvard. This identical experiment has been tried for a period of more than four years in Columbia College; and it is this fact which has induced me to intrude the expression of my opinions into this discussion.

More than four years have now elapsed since the ordinary modes of compulsion, by which the attendance of students upon scholastic exercises is commonly enforced in colleges, were abandoned in this institution. As a substitute for these, the simple rule was adopted, that any marked irregularity of attendance on the daily exercises should debar the student from the privilege of attending the stated periodical examinations, through which every candidate for graduation is obliged by statute to pass, and to pass satisfactorily, before he can receive a degree in Arts. And, in order to remove any uncertainty which might exist as to the amount of irregularity which should be considered sufficient to deprive an individual of this privilege, the limit of tolerated absences from any particular department of study was put at one-fourth of the total number of exercises in that department. This limit was fixed upon, because it had been already tried, for several years, with results entirely satisfactory, in the School of Mines which is associated with the college, and which is carried on, on the same grounds. Under this system, a student may absent himself without being called upon to assign any reason for his absence. He may, if he pleases, assign such a reason voluntarily, or he may state in advance his desire or intention to be absent from a future exercise, and, in case he does this, a note is made of the reason so assigned, which is preserved for a purpose which will presently appear. In order that he may be always aware of the state of his absence account, a bulletin is kept constantly posted where it is accessible to him, exhibiting the number of his absences from every department separately, up to the current date. The data for this bulletin are derived from the daily reports of the college officers made to the president—each officer presenting his report for the day, immediately after the close of college hours—and from these the proper entries are made in the bulletin immediately. An abstract of this record is furnished monthly to the parent or guardian of every student; so that, if there be any unjustifiable irregularity, it is referred to the authority most suitable to investigate the causes and to apply the proper correction. If, at the close of the session, any student appears, from the record, to have exceeded his limit, in any department, he is notified that he is debarred from examination in that department; and the loss of an examination, in any single department, deprives him of his standing as a candidate for a degree. He is not on that account compelled to leave college. He may continue to attend as before; but, if, on account of growing irregularity, or inattention to study, his attendance should be deemed unprofitable to himself, or prejudicial to others, he may be required to withdraw. In this event, he retires silently, and without censure.

In case a student, whose absences for the session exceed the limit of tolerance, should be able to make it appear that all these absences were occasioned by causes beyond his control, or were otherwise justifiable, the faculty are at liberty, in their discretion, to raise the ban, and to admit him to examination. But, if *a single one* of these absences appears to have been wanton or unwarranted, it is of no avail to him that all the others were unavoidable—he loses his standing as a candidate for a degree.

Under this system an appeal is made to a higher motive than the fear of censure. It is inculcated on the student continually that to attend the college exercises is a privilege and a duty; to be absent a loss and a wrong to himself. And, when this idea becomes familiar, he will not only become habituated to attend from choice, but he will profit more by his attendance, and will less frequently be found endeavoring to beguile the weary hours of his imprisonment in the class-room, by petty frivolities out of harmony with the character for manliness which he should at this period of his life be forming.

As to the results of this system in practice, the following remarks, taken from the annual report of the president of the college to the trustees, in 1869, which represent the facts as they apeared then, may be applied without any important modification to the experience of the more recent years: "The effects of the change have proved a very interesting subject of observation. After the lapse of four entire months, it may be said, of a large majority of the students, that no perceptible difference can be discovered at all in the degree of the regularity of their attendance upon scholastic exercises, as it was rendered before and after the adoption of the new regulations. A certain limited number have never been absent at all. A much larger number have been absent only at rare intervals. A number larger still, while absent more frequently, have not at all increased the frequency of their absences in consequence of the change of regulations. Some of these reside at inconvenient distances, or are liable to interruptions of their regularity from other causes beyond their control. . . . From an inspection of the record, it is safe to say that there are more than three-fourths of the entire college body, whose regularity of attendance has been totally unaffected by the introduction of the new regulations. In regard to the remaining fourth, or probably a proportion less than a fourth, it must be admitted that their irregularity of attendance has sensibly increased. This fact shows a degree of parental indifference or of parental indulgence which was hardly looked for; but the evil, so far as it exists, admits of a simple remedy, since the cause is obvious. The inspection of the record makes it quite evident that there is no necessity to make so large an allowance for occasional absences as one-fourth of the entire number. The majority of the students are probably not absent one-tenth of the number. It is practicable, and may be advisable, to reduce this latitude to one-sixth or one-eighth, or even to a less proportion, and the evil will inevitably disappear."

As yet, however, it has not been thought necessary to resort to the expedient here indicated; and, though, in the statutes of the college as they stand, the power is vested in the faculty to apply coercive measures to enforce attendance, this power has never been resorted to, nor has the evil increased. In occasional and very rare instances, a student has been obliged to withdraw from college on account of persistent irregularity or neglect of study; but this by no means more frequently than had been the case under the system of coercion. One quite effectual corrective, applied with us in cases of this kind, is, to require a student deficient in scholarship to study out of college hours under a private tutor, while still continuing his attendance with his classes; and to make his restoration to regular standing as a candidate for a degree dependent on the presentation of a certificate from his tutor, attesting his faithful attention to the studies prescribed, and his satisfactory proficiency in them.

The expedients here described, by which we aim to hold students in college to the proper discharge of their duties, may be said perhaps to partake, after all, of the nature of coercion; but they are not coercive in the sense in which that word is usually employed, when it implies a system of pains and penalties which offend a young man's self-respect, and carry with them, more or less, a sense of disgrace. If they are coercive, they are so precisely as the rules of morality or of gentlemanly propriety are coercive, by operating on the conscience; or as the suggestions of prudence in the ordinary affairs of life are coercive, by constraining men so to govern their conduct as not to prejudice their substantial interests. This is a kind of coercion under which we should desire all young men, and all men of every age, to be placed. It is in itself an educational influence, and one of the most salutary to which men can be subjected. When all our colleges shall have seen their way to the adoption of a regimen like this, as sooner or later they inevitably will, we may hope to see the complete disappearance of that spirit of frivolity which too generally prevails at present among their inmates, and which President Eliot mentions to deprecate—a spirit already declining even in the absence of the healthful influence which the system I have attempted to describe brings with it, and which, though not yet wholly extinct, survives rather as a pernicious inheritance from other times, than because, in the conditions of modern educational institutions, it finds any thing properly congenial to its maintenance.

With one further remark I conclude. It is experimentally proved that no system of compulsory attendance in college is necessary to secure faithful attention to their duties and a conscientious improvement of their opportunities, on the part of that large proportion of undergraduate students whom collegiate education is likely to benefit. That smaller proportion, who will always neglect their duties if they can, will not greatly profit under any system, whether of absolute freedom, or of coercion, however rigorous. I am unable to perceive the wisdom of adapting systems of control with special, or, I may say, exclusive, reference to the case of those who least deserve to be considered, and out of whom the least is likely to be made; especially when this can only be done by depriving the rest of what seems to me to be one of the most felicitous moral influences which can surround and accompany them during the period of their education.

Very respectfully yours,

F. A. P. Barnard.

Columbia College, *April* 2, 1873.

THE DANGERS AND SECURITIES OF SCIENCE.

To the Editor of the Popular Science Monthly.

Mr. Editor: I listened, among others, to the speech of Mr. Parke Godwin at the Tyndall Dinner, and have been much interested both in the speech and in the discussions which have grown out of it. Of course, we cannot all expect to view the most important subjects in the same light, but I feel sure it is a mistake to attribute to Mr. Godwin any thing like a spirit of opposition or depreciation toward scientific progress or preëminence. On the contrary, what he said was, we believe, wholly in the interest of science. He simply gave expression, in unusually elegant and forcible language, to ideas which are entertained of late by many professionally scientific men. He did not propose to cramp scientific inquiry, nor to limit, in any way, its powers or its results, but only to prevent its contamination by what would degrade and cripple it. His speech, as we understand it, was a protest, not against science, but in its behalf, and against the damaging influence of pretended followers or mistaken friends.

There is no danger now that science can ever suffer from the attacks of its enemies, unless it be first debauched by the folly of its own partisans. Its progress for the last hundred years has been a series of triumphs, so numerous and brilliant that nothing else is now in a position to stand against it. And it owes this success entirely to the fidelity with which it has pursued its legitimate course, and the steady determination with which it has adhered to the method of strict scientific observation. For a long time we have given up the notion of the old philosophers, that men could discover things by thinking about them; and have only considered it worth while to spend our time in the investigation of actual phenomena. What has been, for the last half-century, the invariable demand of the world of science upon its votaries? Whenever any one made his appearance with a new claim to attention, the scientific public said to him, in effect: "What is that you have to tell us of this new body or substance? We do not wish to hear what you *think* about it, but only what you *know*. How much does it weigh? What are its form and structure? What are the actual results of its chemical analysis? What phenomena does it exhibit under special conditions? If it be a peculiar force or mode of activity, instead of a material substance, what are the exact conditions of its manifestation, and what are the results of its action, in quantity as well as in kind?"

This is the healthy and nutritious food upon which science has grown to her present proportions. In following such a track with such unswerving patience, she can never make a mistake. But, the moment she leaves this path, she is in danger, or rather she is sure to go wrong, because whatever works by other than scientific methods is not science, and at best can only put on a kind of scientific garb, and masquerade in scientific phraseology.

Are there not some indications that we are not yet altogether beyond this danger? Are we not even more or less exposed to it at this particular time? Some scientific writers are certainly disposed to talk quite as much about their conclusions and theoretical explanations as about the phenomena they describe. There is no harm in this (except that it occupies a good deal of time that might be otherwise employed), provided they keep the boundary-line well marked between what they know and what they think on the subject in question. But they do not always do this. The hypothetical explanations are sometimes erected into a law, or principle, or theory, which, in the author's mind, evidently overshadows in importance every thing else. So we are sometimes supposed to have acquired a valuable piece of information when we are only, as the French say, "getting our pay in words." How much has been said and written for the past few years about *protoplasm!* Now, a student of physiology would be very excusable for thinking, from the manner in which this term is used, that protoplasm was some newly-discovered and important substance, with definite physical and chemical properties, and of the highest consequence in regard to vital organization. He would be considerably disappointed on finding it to be only a word representing a certain set of ideas, or at best a group of many various substances, each one of them specifically different from the rest.

There is even a certain kind of authority claimed, at least by implication, for some of these theoretical notions; and there is no doubt that they are occasionally assigned an established position as accepted truths, to which they are very far from being entitled. If it were not so improbable that Science could ever be induced to imitate in the least degree her old theological enemy, we might suspect even now a disposition in some minds to frame for us a sort of scientific Nicene Creed, the merit of believing in which would not depend exclusively upon the possession of sufficient reliable evidence. If such a creed were drawn up just at present, it would probably read something like this:

I BELIEVE in the Darwinian Theory;
In the Evolution Hypothesis;
In the Undulation of Light and the Luminiferous Ether; and
In the Atomic Constitution of Matter.

Now, we all know that theories are useful in their way, if confined within a very small compass, and employed only to stimulate rather than satisfy inquiry, and to suggest the direction in which new facts may be discovered. But, when they are raised to a higher dignity, and demand our belief in them as representing the actual constitution of Nature, then they are a misfortune to everybody concerned. If we treat them with any more respect than they deserve, we shall suffer for it inevitably by the loss of something which is infinitely more valuable than any of them. The records of the immediate past show the achievements which have been accomplished by means of strict adherence to exact methods of investigation. Should the scientific mind of to-day become ever so little intoxicated with its success, and undertake to decide questions which are beyond its horizon, it will certainly stultify itself, and lose the universal support and confidence which it has now so fairly acquired. For that reason I think that Mr. Godwin, in his Tyndall Dinner speech, was doing good service for science and scientific men, and that we are indebted to him for placing in a very distinct light the only source of danger for scientific interests in the future. J. C. D.

A CORRECTION.—LETTER FROM PROF. TYNDALL.

It is well known that many religious newspapers construed several of the speeches at the Tyndall banquet as righteous rebukes of the guest of the evening, on account of his irreligious science. His statement below was called out by a leading article in the *Christian Intelligencer* of February 13th, entitled "The Tyndall Banquet," from which the following is an extract: "A more significant farewell a visitor has never received at our hands. Prof. Tyndall was welcomed among us as a man of science. It was known, indeed, that he claimed, in that character, a warrant to question some popular religious faiths; but we may safely say that the professors of those faiths never supposed that he would carry his assumed warrant upon the platform and into his lectures on 'Light.' Yet he did that very thing, attacking, in those lectures, both our religious faith and one large class of its professors. Moreover, when the assaults thus made were formally complained of, he expressed no regret for them. Indeed, lest even so significant silence might fail to be appreciated, he now took pains to emboss upon his farewell speech the following remarkable sentences: 'Were there any lingering doubt as to my visit at the bottom of my mind; did I feel that I had blundered—and, with the best and purest intentions, I might, through an error of judgment, have blundered—so as to cause you discontent, I should now be wishing to abolish the doubt, or to repair the blunder; but there is no drawback of this kind.' After this unusual assertion of his perfect satisfaction with his course, it would have been unjust, both to him and to a very large part of his American audiences, to suffer him to depart without some weighty reminder of his mistake."

Of Dr. Hitchcock's address the writer remarks: "The few opening sentences which have thus far been printed indicate the dignified and manly tone in which American Christians resented, through him, the effort of one sort of science to disparage religion;" and he then says: "But Dr. Hitchcock did not stand alone. He had sympathizers enough among his hearers to indorse his expressions with repeated applause; and, what was even more significant, he found the heartiest support in the speech of Parke Godwin, who followed him, speaking for the press. The fact that a clergyman should vindicate the claims of religion, even at a dinner given in compliment to one of his assailants, might not seem in any way remarkable or important. But the editor of the *Post* had no professional zeal to rally him to the same battle; and when, after a detail of some of the most arrogant assumptions of irreligious scientists, he proceeded, with indignant eloquence, to remand their science to its own exact sphere, and to claim for revelation the settlement of the questions of 'primal origin and ultimate destinies,' Mr. Tyndall must have had a complacency quite impervious by ordinary weapons, if he persisted in thinking he had 'made no blunder,' and had 'caused no discontent.' Did Mr. Godwin suppose that the sentiments he was uttering were those of his guest? Did not he and all the company know they were not? Then, did he in uttering them, and they in applauding them, offer a gratuitous insult to the man they pretended to honor? No; but they did a loyal duty to the religion which he had wantonly assailed. They set a stint to their courtesy to the man, lest the excess of it should make a betrayal of their faith."

Upon which, Prof. Tyndall remarks as follows, in a letter to a friend:

"I confess to reading with some amazement the article on the 'Tyndall Banquet,' in the *Intelligencer*. I am there charged with attacking, in my lectures, both the Christian faith and one large class of its professors. If the telling of the truth be a necessary entry on the passport to 'the better land,' then, assuming the maker of this charge to be *not* in a state of invincible ignorance, I would not exchange my chances on the frontier of immortality for his. The fact is that, though solicited to do so, I steadily refused to quit the neutral ground of the intellect during my visit to the United States. My audiences in Boston, Philadelphia, Baltimore, Washington, Brooklyn, and New Haven, can testify whether a single word relating to religion was heard in any lecture of mine delivered in those cities. New York can answer whether, in five out of the six lectures there delivered, a syllable was uttered, *pro* or *con*, regarding religion. And I confidently appeal to that heroic audience which paid me the memorable compliment of coming to hear me on the inclement night when the words were spoken on which this charge is hung, whether, as regards its substance or its tone, what I then said could, with fairness, be construed into an attack 'upon religious faith, and one large class of its professors.' Put my words and manner before them, and I would fearlessly trust to the manhood of any Young Men's Christian Association in the Union for a verdict in this matter. The writer in the *Intelligencer*, moreover, fails to see one conclusion to which his assertions inevitably lead; for, were they true, the perfectly unmistakable manner in which the 'attack' was received by the audience would prove the state of 'religious faith' in New York to be the reverse of creditable to him and others who have the care of it.

"The head and front of my offending hath this extent: At the conclusion of one of my lectures, I referred, for two minutes, in mild language, to the reported words—*reported, I would add, by a Presbyterian*—of the intemperate occupant of a single Presbyterian pulpit, and this is wilfully twisted by that occupant into an attack upon the Presbyterian body. The charge, as originally made, and as now echoed by the *Intelligencer*, is so silly that I did not think it worth public refutation. Why should I care about refuting it, when the sympathetic kindness of the very men I was reported to have assailed assured me that they did not believe a word of the indictment? I carried no more pleasant memory with me from the United States than that of my reception at the Presbyterian College of Yale. The high-minded youths and cultured gentlemen whom I met there, as indeed the Presbyterian body generally, a few hot-headed fanatics excepted, knew how to rate at its proper worth the statement of Dr. Hall, and they will, I am persuaded, assign to its echo in the *Intelligencer* the self-same arithmetical value.

"Should you deem this letter, or any part of it, necessary to public enlightenment, you are at liberty to make public use of it.

"Ever yours faithfully,

"John Tyndall."

EDITOR'S TABLE.

GEOLOGICAL SURVEYS IN THEIR EDUCATIONAL BEARINGS.

THE proposition of Prof. Leeds, in his article on "State Geological Surveys," to link these undertakings to the collegiate institutions of the country is a novel and very important one, and deserves the serious attention of all the friends of scientific education. After stating the aims and necessities of these surveys, the writer shows how college talent might be pressed into their service, and points out the advantages that would arise both in giving thoroughness to the work, and in diminishing its expense to the State. Prof. Leeds confines himself mainly to the consideration of economy, thoroughness in the performance of the work, and the interests of the survey itself. But such a measure could not fail to yield double advantages: it would be as good for the colleges as for the exploration. On educational grounds alone, nothing could be more desirable than to effect this arrangement, and give the colleges business of the kind contemplated.

A geological survey is but a systematic scientific inquiry into the structure and resources of a given region of country. It investigates the strata of the earth and their mineral and organic contents, both to find out how they are constituted, and to contribute useful productions to the arts and wants of society. In its full scope it inquires into the physical features of the region, its agricultural adaptations, its vegetable productions, its forms of animal life in earth, water, and air, its atmospheric conditions, salubrity, and general climatology. In short, it embraces a very full research into those facts of Nature which it is important for the community to know, and the business of science to determine. But the colleges have, for one great object, the teaching of those very things. A portion of their professors are devoted to it, of course under the assumption that they are competent to carry it on.

Now, the result of such an alliance as is here proposed could not be other than salutary upon the institutions themselves. The effect of giving them a certain definite and responsible scientific work in their localities, the results of which would be brought to the test of public criticism, would inevitably be to elevate and sustain the standard of instruction in their laboratories and lecture-rooms. It is a grave difficulty with these higher institutions that their work cannot be brought to judgment and submitted to fixed and recognized tests. They are often the places for careless, slipshod, and aimless work. Mental results are not easy of inspection or valuation; sham and cram are showy and telling, and the constant temptation is to put them in the place of solid attainment; and, when college authorities can constantly fall back upon the pretext that their aim is *discipline*, and that knowledge is a quite subordinate matter, they open a door which allows any amount of loose and slovenly work, and at the same time permits the teachers to escape responsibility and criticism. But if a college were publicly placed in the scientific charge of the region in which it is situated, and required to make such reports thereof as could be accepted for guidance by the community, and brought into conspicuous comparison with similar work in other localities, the whole being under the supervision of able superintendents, a standard would be introduced that could not fail to give a high and authoritative tone to the work of the place.

But the effectual carrying out of the plan now proposed would not only insure able and qualified men as professors, but much more; it would call the students to the work, and secure the grand object of scientific education by bringing their minds into direct and systematic relation with natural phenomena. It would bring them out of their dormitories and class-rooms into the field, and, while favoring health and cultivating a sympathy with natural things, it would bring to bear the stimulus of curiosity and the love of search, while the intellectual work, being of the nature of independent observation and discovery, would be promotive of self-education—the best of all education. It is as notorious as it is deplorable that the scientific teaching of our colleges is grossly defective. Geology, botany, chemistry, physics, and zoology, are taught from books like Latin and history, with the aid, perhaps, of a few demonstrations by the lecturer. The information acquired is superficial and second-hand, and does not deserve the name of scientific knowledge. We believe the effect upon students of bringing them into close mental relation with surrounding Nature, of putting them in charge of a district, and requiring them to observe, classify, and describe its various objects, under the incitement that their useful work would have fair recognition, would be to give inspiration to study, solidity to acquirement, and the highest possibilities of usefulness to subsequent life.

An important consequence of such a plan would be, the growth of scientific museums which would represent the character and resources of the locality. As there is no educational appliance more important than a good museum, so there is no educational process more valuable than the formation of it. Those crude, miscellaneous, rubbishy collections of curiosities, and odd things gathered by accident, that are often thrown together, without method, in some unappropriated corner of an institution, are not entitled to the name of museums. Specimens are nothing except as illustrating ideas, and they require to be so arranged as to teach the science to which they belong. As we ordinarily find them, museums are hardly more instructive than so much blank space. A good local collection should represent, in its specimens, the zoology, botany, and geology of the district. It should be arranged with a view to teaching, and, instead of being crowded with a multiplicity of objects, should consist of carefully-selected, well-arranged, and clearly-labelled *types* of the classes, orders, families, and leading genera of animals and plants, extant in the region, and gathered in their fossil vestiges, from its geological formations, which are at the same time represented by classified minerals.

The plan now suggested, by which it would become the official duty of college authorities to bring together the products of a region, so that they would be accessible to everybody in quest of this kind of information, and at the same time tributary to the purposes of science, would give us museums worthy of the name, and secure the proper objects of their establishment.

In every aspect, therefore, the project of establishing so close a connection between State geological explorations and our higher educational institutions is to be cordially commended; and it is not the least of its advantages that it coincides with the great tendencies of educational reform, and offers an efficient method of carrying it forward.

SCIENTIFIC THEORIZING.

In our correspondence for this month will be found a letter from a distinguished American physiologist, approving the position taken by Mr. Godwin in his speech at the Tyndall dinner, as "a protest, not against science, but in its behalf, and against the damaging influence of pretended followers or mistaken friends;" and this view expresses, we are assured, the conviction of many professionally scientific men of the present time.

We have no desire to prolong controversy, but, with all respect to the professional authorities, we must continue to think that the efforts to limit and confine scientific investigation in the present age are not in the interest of true science; nor can we see how they differ from attempts to obstruct the advance of thought that have been made in preceding ages. There has always been a party unwilling to allow science to find its own limits. They have forbidden each step of its progress, and demanded that it should keep within its sphere, for the sake of its own good. They have never denied science, or questioned its authority, but only demanded that it should consult its own interests by staying in its proper place. When the work of investigating Nature was seriously commenced, some three or four centuries ago, "Aristotle," "Galen," and "Mathematics," were terms used to define the scope of legitimate science; and, when the first great step forward was taken, and men began to question the tradition of the flatness of the earth, they were sharply met with the charge that they were going beyond their sphere and damaging science itself. Men were as free as the wind to pursue true science—that is, to accept Aristotelian and Galenic dicta, and to cultivate the whole range of mathematics. The ideal world was a sphere of exact and eternal truth; external Nature was a mere flux of sensuous appearances, not suspected to be a sphere of law; the attempt to study her was therefore to invade the ancient and inviolable limits of science. Hence, in denying the flatness of the earth, and affirming its sphericity, the early inquirers not only shocked common-sense but were charged with violating every canon of established scientific method. Exactly the same considerations that are now urged were urged then with tenfold force, and the antagonists of the new doctrine might well have said that they "did not propose to cramp scientific inquiry, nor to limit in any way its powers or its results, but only to prevent its contamination by what would degrade and cripple it." And these tactics have been repeated at every great step of advancement. It is never genuine science that breaks over the old limits of opinion, but always "pretended science," "pseudo-science," and "science falsely so called."

In our correspondent's opinion, science has now attained a position in which it holds its destiny in its own hands, and is in no danger save from the folly of its own partisans. His theory of the case is, that science is now endangered by excess of theory. But, if that be the case, it is threatened by its own breath of life. A theory is only a view taken by the mind in its effort at explanation, and cannot be dispensed with, if observation and experiment are to be put to their true use. He says that science demands of its votary, "not what you *think* about it, but what you *know*." But what is knowing but thinking brought to the highest certainty? and how can this end be reached except by the successive steps of conjecture and hypothesis? As Dr. Whewell observes, "To try wrong guesses is apparently the only way to hit upon right ones." It is not Science which puts an embargo upon thinking and theorizing, for it is by these that all her laws have been arrived at. Of course, science demands certainty, demonstration, and experimental exactitude, if obtainable; and if not, then the nearest approach to them possible; but these must have an ideal and a meaning, or there can be no science. Science is not manipulation, but the thinking that accompanies it, and the theory or view that is established by it. Under the rigid rule laid down by the writer, the giant intellects who have made the epochs of science could never have got a hearing. Copernicus, Galileo, Columbus, Newton, Harvey, Dufay, Young, and Dalton, are known to the world as *thinkers*, and have gained immortality in science, and guided the multitude of lesser men by their *theories*. Faraday remarks that the world little knows how many conjectures and hypotheses, which arise in the minds of philosophers, are crushed by the severity of their own adverse criticism; but the world does know something of the number of theories that are submitted to the tribunal of science, and are crushed by the adverse criticism there encountered. Are these efforts of theory, therefore, in either case, to be interdicted or discouraged? Our correspondent has little patience with theories, but they are the measure of mental activity and the essential form of its scientific expression, as their inexorable testing is the measure of sound scientific method. There may be peril in theorizing, as there is in steam, but it is the condition of getting on; and, because brakes are useful, let us not put out the fires.

If there is more theorizing now than ever before, it is because there is far more extensive scientific activity. There is, indeed, greater demand for it now than ever, for the numbers of observers and experimenters who either cannot think or are afraid to think have greatly multiplied in recent years, increasing the mass of observations and fragmentary results, which can only be organized into accepted theory by the highest order of minds. Generalizations and inductions which bind up isolated facts in manageable form, and which constitute the very texture of science, are only to be arrived at by thinking and theorizing. And with the multitude of men thoroughly trained in all departments, and sharpened to the work of criticism, there is certainly less danger now than ever that worthless theories should gain the ascendency.

The hypothesis, that in future science can suffer no damage save from enemies in its own household, we venture to think, represents but a small portion of the pertinent facts. Much has undoubtedly been gained by past conflict; astronomers are no longer imprisoned, and physiologists no longer roasted. But have ignorance and intolerance been banished from the world? or, remaining in it, have they lost their aggressiveness or their influence over men's minds? Have they, in fact, done more than change weapons? We grant that the antagonism to science has greatly diminished within recent years; but, to say that science has now to encounter no external adverse influences which affect its prosperity, is to talk at random. The world is still dominated by illiberality and prejudice; and when science puts forth ideas that do not square with prevailing belief, as, from its progressive nature, it has always been doing, and must continue to do, it is met with anger and denunciation, which it requires no little moral courage to withstand. It cannot reasonably be claimed that such a state of things is without influence upon scientific interests. It represses the honest and healthy expression of opinion; it checks young men from entering the scientific field; it resists scientific education; and it hinders men of science from obtaining the necessary means for prosecuting their inquiries.

Even our correspondent puts Science upon its good behavior before a censorious world. He affirms that she may incur damage, and is exposed to danger from her enemies, but these evils, it is alleged, can only come from "contamination" and "debauchery" by her own partisans. And what is meant by this language, but the promulgation of doctrines that her enemies regard as odious? Stop a hundred men in the street, and ask them what they consider to be the great contamination and debauchery of science at the present time, and ninety-nine of them will reply, "Darwinism"—the first item in our correspondent's new "Nicene Creed." This is the verdict of public opinion. But we open the new volume of Helmholtz, who is probably the most eminent and authoritative scientist in Europe, and, in his lecture on the "Aims and Progress of Physical Science," we read that "Darwin's theory contains an essentially new creative thought." This is the verdict of science. Is the great German one who brings discredit upon his class by thinking instead of knowing? and is the party which characterizes the creative conceptions of Nature as degradations, to be accepted as the arbiter of the proper limits of science? We remain of opinion that scientific men are the best judges of the legitimacy of their own inquiries, and that they will honor themselves most by the bold and fearless prosecution of these inquiries, let them lead wherever they may.

TO THE PUBLIC.

A BOOK entitled "Youman's Dictionary of Every-Day Wants" is being extensively circulated by canvassers, and I am much annoyed at finding that it is purchased under the impression that it is by the Editor of THE POPULAR SCIENCE MONTHLY, and the author of the "Hand-Book of Household Science," "Chemistry," etc. I am neither the author of it, nor have I had any thing to do with its preparation; and, in so far as my name has been used to sell it, it is a fraud. It will be an act of justice to the public, as well as to myself, if the press will kindly reproduce this card. E. L. YOUMANS.

LITERARY NOTICES.

LESSONS IN ELEMENTARY ANATOMY. By ST. GEORGE MIVART, F. R. S., etc. Macmillan & Co., London and New York, 1873.

THIS is a companion volume to Huxley's "Lessons in Physiology" and Oliver's "Lessons in Botany," and is devoted mainly to a description of the human body, with only so much of the anatomy of the lower animals as will serve to illustrate the variations which corresponding organs exhibit in the inferior vertebrates. The first chapter begins with a general survey of the structure of the human body. This is followed by a brief account of the classification of animals, in which the author, adopting the more modern views, names seven sub-kingdoms, illustrating each with the figure of some typical form. The characters, more or less common to all animals, man included, are next pointed out, when leave is taken of the invertebrates, and a consideration of the principal subdivisions of the group or sub-kingdom to which man belongs closes the chapter. The six succeeding chapters, or lessons, taking up in all 218 pages of the book, are upon the skeleton, wherein the various systems of bones are treated, each being described, first, as it is developed in man, and then as it appears in homologous parts of other vertebrates. The reasons given by the author for allotting so much space to this dry subject are: "1. The general resemblance borne by the skeleton to the external form. 2. The close connection between the arrangement of the skeleton and that of the nervous system, muscles, and vessels. 3. The relations borne by the skeleton of each animal to the actions it performs, i. e., to the mode of life and habits of the various animals. 4. The obvious utility of the skeleton in classification and the interpretation of affinity. 5. Parts of the skeleton or casts of such are all we possess of a vast number of animals formerly existing in the world, but now entirely extinct; a good knowledge of the skeleton must, therefore, be of great utility to those interested in palæontology." Lesson eight, occupying the next 64 pages, is on the muscles, which are dealt with in the same manner as the bones—that is, they are first described as they exist in man, the more important deviations from this type in other vertebrate animals being afterward pointed out. The same method is pursued in the four remaining lessons, which are on the nervous, circulatory, alimentary, and excretory systems, respectively.

The book closes with a tabulated summary, first, of the characters which distinguish man from the animals belonging to the four lower classes of the vertebrate sub-kingdom; and, second, of the characters which separate him from all other mammals. The volume is clearly printed, has a very full index, and, on the whole, seems well suited to the use of teachers and others who already know something of the subject. But for beginners we doubt its utility, as it is altogether too technical to be attractive to them, and too closely written to be readily grasped by minds unfamiliar with this class of subjects.

Antiquities of the Southern Indians, particularly of the Georgia Tribes. By Charles C. Jones, Jr. New York: D. Appleton & Co., 1873.

This work is devoted to a consideration of the monuments, relics, and ancient customs of the aboriginal population formerly inhabiting that portion of the United States which is now comprised within the limits of Virginia, the Carolinas, Georgia, Florida, Alabama, Mississippi, Louisiana, and Tennessee. The antiquities of Georgia receive special attention, for with them the author is most familiar. But, as all the tribes occupying the territories indicated above had almost identical customs and arts, what applies to one section will apply to all, as the author well shows. We think, however, that he ought to have made an exception of the Natchez, who were sun-worshippers, and, in virtue of that higher grade of fetichistic religion, raised considerably above the neighboring tribes. But the author has no ambition to philosophize about the religious or *cultural* status of the extinct peoples whose memorials he has exhumed. He simply narrates what he has seen, citing here and there the notes of ancient and modern travellers to show the purpose of an artificial mound, or moat, or plateau, or the meaning of an outlandish ceremony, etc.

The first three or four chapters of the work give an account of the *habitat*, the physical characteristics, manners and customs, and arts of the Southern Indians, at the period when first they came in contact with men of European race, and particular attention is bestowed upon their costume, manufactures, ornaments, games, festivals, marital relations, forms of government, religious ideas, and funeral customs. The remainder of the book, and its larger portion, classifies and describes very fully the various monuments of early constructive skill, implements, utensils, ornaments, and manufactures of these primitive tribes.

The illustrations consist of 31 plates and several woodcuts of objects mostly in the author's private collection, which are here figured for the first time.

THE CHILDHOOD OF THE WORLD. By EDWARD CLODD. London and New York: Macmillan, 1873.

THIS is, we believe, the first book of its kind that has ever been published, at least in English—a primer of anthropology and archæology, giving the results of advanced modern science, and intended for the instruction of young children. It is written in attractive style, and is sure to gratify the young folk. The author contrives to convey a very large amount of information in very small space and in very simple language; he can simplify without debasing, and can instruct the young, without ever resorting to unworthy tricks or making drafts on their credulity, which maturer years would lead them to discount. The paper, print, and binding of the book, are all that could be desired.

THE MECHANISM OF THE OSSICLES OF THE EAR AND MEMBRANA TYMPANI. By H. HELMHOLTZ. Translated from the German, with the author's permission, by ALBERT G. BUCK and NORMAND SMITH. New York: Wm. Wood and Co., 1873.

IN this little work Dr. Helmholtz comes before the world bringing the results of his own observation, and, as a matter of course, he pours a flood of light upon the subject which he treats. The essay is intended for professional men, and for students familiar with physiological science, and both these classes of readers will find here the only treatise in any language which discusses fully the anatomical, physiological, and mathematical aspects of the matter in hand.

BOOKS RECEIVED.

Logic of Medicine. By Edward S. Dunster, M. D. New York: D. Appleton & Co. 1873.

The Criminal Use of Proprietary and Advertised Nostrums. By Ely Van de Warker, M. D. New York: D. Appleton & Co., 1873.

The Short-Footed Ungulata of the Eocene of Wyoming. By Edward D. Cope.

Criminal Responsibility of Epileptics. By M. G. Echeverria, M. D.

New Method of preserving Tumors, etc., during Transportation. By Joseph G. Richardson, M. D. Philadelphia: Lippincott, 1873.

Mechanism of the Ossicles of the Ear and Membrana Tympani. By H. Helmholtz. New York: William Wood & Co., 1873.

The Scientific Bases of Faith. By Joseph John Murphy, Author of "Habit and Intelligence." London and New York: Macmillan, 1873.

The Unity of Law; as exhibited in the Relations of Physical, Social, Mental, and Moral Science. By H. C. Carey. Philadelphia: Henry C. Baird, 1873.

The Romance of Astronomy. By H. Kalley Miller, M. A. London and New York: Macmillan, 1873.

The Childhood of the World; a Simple Account of Man in Early Times. By Edward Clodd, F. R. A. S. London and New York: Macmillan, 1873.

The Sanitarian. A Monthly Journal. A. N. Bell, M. D., Editor. New York: A. S. Barnes & Co., 1873. $3.00 *per annum.*

Prayer and the Prayer-Gauge. By Rev. Mark Hopkins, D. D. Albany: Weed, Parsons & Co., 1873.

The Upper Coal-Measures west of the Alleghany Mountains. By John J. Stevenson. Salem, Mass., 1873.

MISCELLANY.

Action of Drought and Cold on Forest-Trees.—In an able paper on the manner in which the distribution of plants and animals may be influenced by extraordinary changes in the character of the seasons, published in the *American Naturalist* for November last, Prof. N. S. Shaler attributes the wide-spread destruction of evergreen trees, which became so painfully apparent during the previous spring, to the action of drought and cold. The year preceding was, in New England, one of the dryest on record, the ground, when winter set in, holding a comparatively small amount of moisture. This left the roots of trees deficient in sap. Not being well protected by snow, the ground in winter was frozen to a great depth, and, as the frost left the roots in spring, they remained for some time in contact with relatively dry earth, thus causing a shock too great for their vitality to withstand. During the succeeding summer Prof. Shaler also observed a remarkable scarcity of snakes and toads, which he is likewise inclined to ascribe to the great severity of the previous winter. Concerning the effect of such climatic accidents on the character of our forests, he says:

"Small as the destruction of forest-trees is, it will doubtless add several per cent. to the deciduous trees of New England, and remove an equal amount of conifers. The conifers seem to be relics of an old time, and not competent to wage a successful war with their younger and more elastic competitors, the oaks, beeches, and other deciduous trees. Every gap that is made in our forests of cone-bearing species is filled not with their legitimate successors, but by forms from the other class of trees. Let us suppose that the shock of the last season had been great enough to kill off the whole of our pines, the result would have been a complete change in the character of our forests; oaks generally would take the vacant place. This would affect the character of the undergrowth very materially, for the lesser plants of a pine-wood are very different from those which flourish beneath oaks. This would have had a very great effect upon insect-life, and more or less directly influenced the number and character of the birds and the mammals. Even the climate would be in some small measure influenced, for a pine-forest retains the snow better than one which loses its leaves in the winter, and thus tends to secure a more equable temperature in the region where it lies. Thus we see that an accidental drought might bring about a change in the assemblage of vital conditions on the surface of the land, as great as those which, when recorded in strata, we accept as indicating distinct geological formations."

Dental Art among the Japanese.—Dr. W. St. George Elliott, formerly of this city, now at Yokohama, Japan, sends to the *Dental Cosmos* an interesting account of Japanese habits in regard to teeth, and of the state of dentistry in that empire. He says that the teeth of the daughters of Japan are objects of envy, and it is remarkable that a nation who place so much value upon their teeth should keep up the custom of blacking them after marriage. As a race the Japanese have not good teeth, and it is rare to find an old person with any at all. Their tooth-brushes consist of tough wood, pounded at one end to loosen the fibres. They resemble paint-brushes, and owing to their shape it is impossible to get one behind the teeth. As might be expected, there is an accumulation of tartar which frequently draws the teeth of old people. The greatest accumulation is behind the lower orals, and these are frequently cemented together by a dense, dark-brown deposit, a quarter of an inch in thickness. Their process of manufacturing false teeth is very crude. The plates are made of wood, and the teeth consist of tacks driven up from the under side. A piece of wax is heated, and pressed into the shape of the roof of the mouth. It is then taken out and hardened by putting it into cold water. Another piece of heated wax is applied to the impression, and, after being pressed into shape, is hardened. A piece of wood is then roughly cut into the desired form, and the model, having been smeared with red paint, is applied to it. Where they touch each other a mark is left by the paint. This is cut away until they touch evenly all over. Shark's-teeth, bits of ivory, or stone, for teeth, are set into the wood and retained in position by being strung on a thread which is secured at each end by a peg driven into the hole where the thread makes its exit from the base. Iron or copper tacks are driven into the ridge to serve for masticating purposes, the unequal wear of the wood and metal keeping up the desired roughness. Their full sets answer admirably for the mastication of food, but, as they do not improve the looks, they are worn but little for ornament. The ordinary service of a set of teeth is about five years, but they frequently last much longer. All full upper sets are retained by atmospheric pressure. This principle is coeval with the art. In Japan, dentistry exists only as a mechanical trade, and the status of those who practice it is not very high. It is, in fact, graded with the carpenters—their word *hadyikfsan* meaning *tooth-carpenter*.

Vegetable Ivory.—The kernel of the corrozzo-nut so closely resembles ivory as to merit the title of vegetable ivory. The plant (*Phytelephas macrocarpa*) which produces this nut belongs to the palm-tribe. It grows in South America, and possesses extraordinary beauty. The stem is short, and lies along the ground, but from its crown issues a sheaf of light-green, pinnated leaves, like ostrich-plumes, which often attain a height of 30 or 40 feet. The fruit of the plant is as large as a man's head, and contains a number of nuts of rough, triangular shape, each being almost as large as a hen's-egg. When fully ripe, the kernel of the nut is very hard and white, and hence the name phytelephas (*vegetable ivory*). This is now largely used as a substitute for elephant ivory, in the manufacture of buttons and various ornaments, and might easily pass for the animal product. Indeed, the best judges are often deceived by the close resemblance between the two. Advantage is taken of this circumstance in Germany by dealers in bone-dust to adulterate their wares with the waste of the factories where the vegetable ivory is manufactured. The best mode of detecting the adulteration is to burn the suspected article. If it contains any considerable amount of the vegetable substance, the application of heat will cause it to give out an odor much like that of roasting coffee; but, if it is pure bone-dust, or nearly so, it will emit a nauseous and very disagreeable stench.

Coloring Matter in Blood.—A writer in Virchow's *Archiv* finds in blood two distinct coloring-matters. One of these is readily soluble in water and alcohol, but not so readily in ether. When dry it has a dark, greenish-brown color, and is carbonized on the application of heat, without ebullition. The ash is strongly colored with iron, and contains phosphoric and silicic acids, and a trace of alkali. It does not yield hemin-crystals under any treatment. With guaiacum-tincture and turpentine-oil it gives the well-known blue color, and under the spectroscope is found to possess the characters attributed to alkaline oxyhematin by Preyer. It appears to be identical with Von Wittich's hematin. The other coloring-matter consists of dark, blue-black microscopic crystals, insoluble in water, alcohol, ether, chloroform, and acids, but soluble in weak alkaline solutions, to which they give a brownish tint. If it be then precipitated by acetic acid, and dried, it will, on being treated with sal-ammoniac and glacial acetic acid, yield beautiful hemin-crystals. When reduced to an ash, it consists of pure oxide of iron. It seems to be identical with Virchow's hematoidin.

Elimination of Carbonic Acid by the Skin.—The amount of carbonic acid given out of the system through the skin in man has been variously estimated by physiologists; but, as their methods of determination were all more or less defective, it is not surprising that their results should differ very considerably from one another. Thus Reinhard's estimate makes the average daily elimination of carbonic acid through the skin about 35 grains, while Gerlach makes it 120 grains; other authorities ranging all along between these two extremes. A special apparatus has been devised by Dr. Aubert, of Rostock, for more accurately ascertaining the amount of this excretion. He seats a person within a box, which fits lightly around the neck, and through which a gentle current of air is passed. Dr. Aubert, in this way, finds that in the course of 24 hours a maximum of 97 and a minimum of 35½ grains of carbonic acid are eliminated by the skin of the whole body, exclusive of the head. Variations of temperature will of course affect the amount of carbonic acid thus excreted. In the experiment, the external temperature was about 86° Fahr.

Remarkable Diamonds.—A diamond was recently discovered, at the Cape of Good Hope, which weighs 288 carats. This the

Builder calls enormous, and accordingly christens the new stone "Queen of Diamonds." But the *Builder* is plainly in error here, for there are many diamonds which weigh far more. Thus, the Grand Mogul is the owner of a rose-diamond which, in the rough state, weighed 780½ carats. It lost very largely in the cutting, weighing now only 136⅞ carats. It is valued at over two and a quarter millions of dollars. A potentate in Borneo owns a diamond weighing 367 carats. The "Regent" weighed in the rough 410 carats. The "Orloff" weighs 194¾, and may have weighed thrice as much in the rough state. An Austrian diamond weighs 139½, and, as the lapidary cannot cut these stones without depriving them of at least half their weight, it must have been, in the rough, larger than the Cape "Queen." But the name given to this newly-found stone will appear still more incongruous when we consider its quality. A diamond is said to be of the first water when it is perfectly limpid and colorless, and free from flaws, and of the second or third water in proportion as it departs from this standard. But this Cape diamond is of a yellow color, and marked with flaws—it is, therefore, not of the *first water*, and would in all probability be classed by the lapidary as of the *third water*.

Production of Sea-Salt in Portugal.—The salines of Portugal, at Setubal, Lisbon, Aveiro, and Algarve, yield annually 250,000 tons of sea-salt. According to Prof. Wauklyn, in the *Mechanics' Magazine*, the process of manufacture at the first-named place is as follows: There is a vast reservoir of about four acres in extent, eight inches deep, and partitioned into squares of about 130 yards in surface. Roads, three feet wide, separate the squares, and the latter all communicate with the main reservoir of sea-water. In autumn the whole salt-marsh is overflowed to the depth of 20 inches. This water evaporates in the spring, the roads appearing above the surface in June. Then the tanks are cleaned out, and afterward left to themselves, and recharged from time to time with new supplies of water. In 20 days a layer of salt over one inch thick is found. This, the first crop, is collected, and the tanks filled again. In 20 days another crop is gathered. If the season is favorable, three crops may thus be collected before September, when the marsh is flooded for the winter.

Controlling Sex in Butterflies.—The *American Naturalist* for March contains an admirable essay by Mrs. Mary Treat, in which she brings a long array of facts to prove that the sex of butterflies depends, in some cases at least, rather upon the external conditions surrounding the larva, or caterpillar, than on its anatomical structure. The results of the author's experiments contradict the doctrine of most entomologists, which asserts that even in the eggs of the *Lepidoptera* the germs of sexual difference may be discerned. The editor of the *Naturalist* quotes from several authorities, to show that, in the case of all animals which reproduce by eggs, the sex is probably determined at or about the time of conception, or at least early in the embryonic stage. Mr. T. W. Wonfor also, writing on "Certain Wingless Insects," in *Hardwicke* for March, asserts that the very same conditions, viz., lack of abundant food, or alternations of scanty and bountiful food, which, according to Mrs. Treat's experiments, determine the sex of the future imago, or butterfly, tend only to "produce dwarfs or monstrosities." The writer in *Hardwicke*, we may add, holds that no sex-difference is discernible either in the eggs or in the larvæ. Mrs. Treat's observations and experiments, it will be seen, were very thorough-going and very carefully conducted, and will, doubtless, attract the earnest attention of naturalists. Some two years ago Mrs. Treat placed a larva, which had already taken some steps toward the chrysalis state, upon a fresh stem of caraway, and was surprised to see it commence eating. It then continued to eat for some days before changing to a chrysalis. She next placed a number of other larvæ on similar stems of caraway, while still others she deprived of food altogether. Those of the last lot which completed their transformations were all males, and all the butterflies from the first lot were females.

The next experiment was commenced in June last. In July the author had about two hundred larvæ feeding at once. Immediately after the last moult, a number of these were shut up in paper boxes, five to ten in a box, and deprived of food. If, two or three days after confinement in the boxes, any of the larvæ were found wandering about, they were fed very sparingly. Nearly all of them lived to complete their transformations. Another lot were, in like manner, put in boxes, but supplied with abundant food. From the latter came sixty-eight females and only four males; from the former seventy-six males and only three females. Five larvæ that were eating vigorously were also taken from their food a day or two before they would have been sated. Of these, four turned out females.

Another experiment was this: Soon after the last moult, twenty larvæ were deprived of food for twenty-four hours. Then ten of them were given abundant food again, as long as they would eat. One of these met its death by accident in the chrysalis state, but all the rest became female butterflies. Of the other ten, two died in the chrysalis state; the remainder were males.

Again: Some twenty half-grown larvæ of the *Vanessa antiopa* were accidentally deprived of food. Twelve of them died of starvation, but the remainder completed their transformations. On dissection, these eight all proved to be males. The indefatigable student pushed her investigations further still, for, having found thirty-three larvæ of an unfamiliar species, she fed them abundantly, till they would eat no more. The rare and beautiful moth *Dryocampa rubicunda* made its appearance in due time, and there were twenty-nine females and only two males, the remaining two having either escaped or died. Finally, a lot of the same species of caterpillars were left without food. Some of them were killed by a parasite, others died of starvation, and the seven which survived were all males.

Hydrophobia and the Imagination.—The period of time which elapses between the bite of a rabid animal and the appearance of hydrophobic symptoms varies over a very wide range indeed. The disorder seldom makes its appearance earlier than the eighth day after inoculation (if inoculation there be); or, again, the virus may be hidden in the wound for weeks, months, or even years. Physicians say that, in most cases, hydrophobia manifests itself in from four to eight weeks after the bite, though there are many authentic cases where the period of incubation extended over eight or nine months, and in one instance even as long as seven years. In this term *incubation* is implied an hypothesis gratuitously assumed, and scarcely susceptible of direct demonstration. It is found that a patient bitten by a rabid animal passes a certain length of time without manifesting hydrophobic symptoms, and it is supposed that the germs of the disease have been slowly maturing. But, as there is no other disease whose period of incubation is so long or so varying in duration, the hypothesis which traces hydrophobia to animal virus finds no foundation in analogy, and is consequently very weak.

It is, therefore, very natural that medical men should begin to study the whole question anew, and attempt other explanations of this disease. Thus, Dr. D. H. Tuke, whose paper on the "Blanching of the Hair" appeared in our December number, has lately published a work on the "Influence of the Mind upon the Body," and there supports the proposition that hydrophobia is produced solely by the action of the imagination. The author cites cases where, beyond all doubt, hydrophobic symptoms were developed without inoculation. A notable instance is that of a physician of Lyons, named Chomel, who, having aided in the dissection of several victims of the disorder, imagined that he had been inoculated with the virus. On attempting to drink, he was seized with spasm of the pharynx, and in this condition roamed about the streets for three days. At length his friends succeeded in convincing him of the groundlessness of his apprehensions, and he at once recovered. Rush also tells of cases of spontaneous hydrophobia, which arose from no other cause but fear and association of ideas.

A German physician, too, Dr. Marx, of Göttingen, as we learn from the *Clinic*, is disposed to take this view of hydrophobia, and to regard it as a psychical affection, the result of morbid excitement of the imagination. He is of the opinion that the bite of a mad dog does not, of itself, produce the symptoms of hydrophobia, and that, were it not for the common belief in canine virus, the spasms and other manifestations of the disease would not supervene. This view is confirmed by the fact that young children, who are not acquainted with the common belief as to hydrophobia, may be bitten by mad dogs and escape spasms and madness. He adds:

"If we are able, as in olden times, and in the case of children, to instruct or induce men to be perfectly quiet after they are bitten by a rabid dog, not to tremble or be frightened, but to banish anxiety, to control their imagination, and, with patience and hope, to look forward to recovery, and also to persuade the well to remain with the unfortunate one, and not to run away, but to cheer him in the hour of trial, then the means may have been discovered by which the effects of the accident are to be banished, and the poison in the wound neutralized."

Odorous and Liquefiable Gases: what Gases may be liquefied.—A writer in the *Pharmaceutical Journal* notes a remarkable relation between the odor of gases and their reducibility to the liquid or solid state. Thus oxygen, hydrogen, and nitrogen, which have no odor, cannot be reduced either by pressure or by cold. On the other hand, chlorine, which has a very strong odor, is easily condensed to a liquid. Again, the protoxide of carbon, being odorless, cannot be condensed, while the dioxide or carbonic acid, which has a faint, pleasant, and pungent odor, can be reduced to a liquid, and even to a solid state. Nitrous and nitric oxide, the latter of which is odorless, show similar phenomena. An exception to the general rule, that gases which are odorous are condensible, is furnished by acetylene, which, though having a faint garlic smell, has never been condensed. Usually condensibility stands in a direct ratio to the strength of the odor possessed by a gas. Thus, sulphurous acid, which has a most intense odor, becomes a liquid under a pressure of two atmospheres, at 15° Fahr., while nitrous oxide, which has but a faint smell, requires fifty atmospheres, and a temperature of 7.2° F. A few gases having a fetid odor are exceptions to this law, but it holds good so generally, that a list of gases, arranged according to their reducibility, and another list arranged according to their properties of smell, will show a rough though marked coincidence.

The Spectroscope and the Bessemer Process.—Prof. Tidy, in a lecture on the spectroscope, thus briefly describes its important practical application in the Bessemer process: "Cast-iron contains a great amount of carbon, and in the Bessemer process this carbon is got rid of by burning it out of the molten iron with a blast of atmospheric air. The fluid cast-iron is placed in a large retort lined with refractory clay. This retort, the *converter* as it is called, turns on a pivot. Through the pivot a tube passes in connection with a very powerful blowing apparatus, by which air can be blown into the molten iron. That air burns out the carbon, the heated gases issuing as a flame from the converter. Now, it is very important to stop that blowing process directly the time arrives. Ten seconds too soon, or ten seconds too late, and the charge is spoilt. Experience, I grant you, does guide the worker, but experience is a costly thing; and this I am confident of: laud experience as you will, it will not weigh down the scale when we have in the opposite pan exact scientific experiment. The Bessemer flame, as it issues from the converter, is examined by the aid of the spectroscope. Numerous substances are visible—sodium, potassium, iron, hydrogen, carbon, etc. All of a sudden, in a second, the carbon-lines disappear, and that is the moment when the air-blast must be turned off, for now the carbon is burnt away, and the iron is converted."

New Material for Illuminating Gas.—*Le Gaz*, the gas-light journal of Paris, calls the attention of the directors of gas-works to a new illuminating material, *vegetable pitch.* This material is made by the Patent Oil and Stearine Company, of England, from the residues of the manufacture of olive, palm, cocoa, and other oils. In England it is widely used, being employed in gas-works in connection with coal, with a view to augment the volume of gas, as well as its illuminating power. The London Gas-light Company constantly employs it, mixing it in certain proportions with the coal, and the Gas Company of the Crystal Palace uses this material only, to produce a rich gas. The pitch is solid and glistening, and distils very rapidly in the common gas-retorts, leaving scarcely any residue. In case a large amount of gas is required to be furnished in a very short time, this property of rapid distillation is of high importance. Its yield of gas is said to be very considerable, being 765 to 850 cubic metres (830 to 930 cubic yards) to the ton. The illuminating power of this gas is equal to that of 33 sperm-candles, 5 to the pound. It is too rich to be used with the ordinary burner. It is best employed to enrich gas made from inferior coals. It contains scarcely any sulphur—0.87 per cent. The analysis of the pitch is as follows: Volatile matter, 74.40; fixed carbon, 21.72; ashes, 3.88.

Antiquity of Man.—The following letter from Sir John Lubbock appeared in *Nature* for the 27th of March: "I have received a letter from Mr. Edmund Calvert, in which he informs me that his brother, Mr. Frank Calvert, has recently discovered, near the Dardanelles, what he regards as conclusive evidence of the existence of man during the Miocene period. Mr. Calvert had previously sent me some drawings of bones and shells from the strata in question, which Mr. Busk and Mr. Gwyn Jeffreys were good enough to examine for me. He has now met with a fragment of a bone, probably belonging either to the dinotherium or a mastodon, on the convex side of which is engraved a representation of a horned quadruped 'with arched neck, lozenge-shaped chest, long body, straight fore-legs, and broad feet.' There are also, he says, traces of seven or eight other figures, which, however, are nearly obliterated. He informs me that in the same stratum he has also found a flint flake, and several bones broken as if for the extraction of marrow. This discovery would not only prove the existence of man in Miocene times, but of men who had already made some progress, at least, in art. Mr. Calvert assures me that he feels no doubt whatever as to the geological age of the stratum from which these specimens are obtained. Of course I am not in a position myself to express any opinion on the subject, but I am sure that the statements of so competent an observer as Mr. Calvert will interest your readers."

NOTES.

The population of France, as shown by the census, was 38,067,064 in the year 1866. The official estimate of annual increase is 130,078—or, for the seven years ending January 1, 1873, 910,546. Total, 38,977,610. But the actual census gave only 36,102,921, showing a loss of 2,874,689. Deduct the official estimate of Alsace-Lorraine, 1,595,238, and the remainder, 1,279,451, represents the decline of population during seven years. The excess of females over males is now 100 per cent. greater than ever before.

The epileptiform convulsions excited by the internal administration of essence of wormwood, and Japan camphor, may, according to recent experiments in France, be effectually prevented by the use of bromide of potassium. This is regarded as additional evidence of the value of the bromide in the treatment of epilepsy.

The medical officer having under supervision the schools for pauper children in three of the parishes of London reports that, among those admitted, from thirty to forty per cent. are afflicted with ophthalmia in some of its stages, and that bringing the children together in this way concentrates and favors the spread of the disease. The immediate cause of the affection in most of these cases is held to be the dirt and dust of the streets which is allowed to accumulate at the inner corner of the eye, where it forms a semi-solid mass which irritates and inflames the lids.

Died, in Jersey City, on Sunday, March 9th, Charles F. Durant, aged 68 years. Deceased was a diligent student of science, and some years since published a valuable work on the "Shells and Sea-Weeds of the Harbor of New York." He was also the author of a work on astronomy, which was printed for circulation among scientific men. In 1833 Mr. Durant made the first balloon ascension ever made in this country. His aërial voyages numbered in all fifteen.

Petroleum has been found in large quantities in Ecuador. Wells have been sunk at various points between the sulphurous springs of San Vicente and the sea-shore. In some of these the petroleum is fluid, like whale-oil, but in others it has the consistence of butter. In the upper part of some of the wells it can be seen in hard, compact masses, which probably have been formed by the evaporation of the more liquid portions.

Mr. William Yates has made the following important modifications in the Davy lamp: He dispenses with wire gauze immediately around the flame, replacing it in front with a strong lens, and behind with a silver reflector. The miner cannot raise the flame so high as to heat the gauze, and, if he would open the lamp, to light his pipe, he is foiled, for that cannot be done, without extinguishing the flame.

A correspondent of the *Lancet* tells of a hen laying a pair of eggs of good average size within the space of ten minutes. The same writer found in his poultry-yard a double egg, or two eggs combined. This is not a case of merely double yelk within one shell, which is common enough, but of two complete eggs, with separate shells entire, except at the points of contact.

In Russia the sunflower is cultivated for the oil which it yields. This oil is used in cooking as well as for lamps, for soap-making, and for making paints. Fifty bushels of seed may easily be grown on an acre of land.

At a recent meeting of the French Academy a magnet was exhibited by M. Jamin which carries more than thirty-two times its own weight, whereas the greatest carrying power hitherto obtainable in artificial magnets has been not above four or five times their weight. Instead of the thick plates usually employed, M. Jamin's magnet is made up of a number of very thin plates superposed on each other, and all thoroughly magnetized. By this contrivance the volume and weight of magneto-electric machines can be very considerably reduced.

It has been shown by M. Bérard that, when fruits are set in the open air or in oxygen gas, a certain volume of oxygen disappears, and at the same time a nearly equal volume of carbonic-acid gas appears in its place. If, however, the fruits are placed in carbonic acid or any other inert gas, there is still produced a notable quantity of carbonic acid, as though by a kind of fermentation; and, since, under these conditions, the oxygen necessary to the change is not furnished by the surrounding medium, it must be supplied by the saccharine matter of the fruits themselves, a considerable part of which is thus transformed into alcohol.

A French horticulturist has perceived that, wherever a fruit—a pear, for instance—rested upon some branch or other support beneath it, that fruit always grew to a large size. The support given to the fruit permits the sap-vessels of the stem to remain open, and the fruit can receive abundant nourishment. Mr. Thomas Meehan made substantially the same observation some years ago.

Eighteen men and 63 women died during the past year in England at the age of 100 years or over. There were still living, when the census was taken, 6 men and 22 women, 100 years old; 1 man and 14 women, 101 years; 3 men and 11 women, 102 years; 2 men and 6 women, 103 years; 5 men and 7 women, 104 years; 2 women, 105 years. A woman died in Huddersfield at the age of 107, and a man in Staffordshire was 108 years old when he died.

On the American Continent, the *Sequoia*, or Big Tree of California, can find a congenial home only in a very few localities. In England, however, it appears to thrive admirably, and various "improved" varieties have already made their appearance there. The *Weeping Sequoia* is the latest novelty.

The ancient Egyptians possessed the art of so tempering bronze that it would take and keep a sharp edge. Sir Gardiner Wilkison found in tombs bronze daggers which were almost as elastic as steel, after having been buried 3,000 years.

Nickel ore has been found cropping out in the counties of Madison, Iron, and Wayne, Missouri; and at Sand Prairie, in the same State, a new lead-mine has been discovered. The prospectors, says the *Iron Age*, took out 4,000 pounds of the mineral three hours after the lead was struck.

One of the chief potato-growing provinces of Holland, Groningen, has thirteen mills devoted to the conversion of potatoes into flour. Nearly the whole crop of the province is thus disposed of, the daily yield of the mills being some 246 tons of potato-flour. A large part of this, according to the *Glasgow Weekly Herald*, is consumed in the adulteration of wheat-flour in England.

According to the French chemist Dumas, the newly-discovered art of decorating walls with tin-foil, bearing designs in oil-colors, has in a somewhat modified form been successfully practised by the Chinese for a long time.

A vein of plumbago, eight feet thick, has been discovered in Missouri. This is the first deposit of this useful mineral found in the West. The vein at Sturbridge, Mass., varies in thickness from one inch to two feet. There are also plumbago-mines at Brandon, Vt., Fishkill, N. Y., Wake, N. C., and St. John's, N. B.

Found *post mortem* in a lunatic's stomach: 44 pieces of shirt, 41 do. pocket-handkerchief, 10 do. caps, 8 do. braces, 7 do. chamber-pot handle, 6 do. stick, 5 do. leather, 4 do. coal, 3 do. stocking, 2 do. rag, 1 do. tobacco-pipe, 1 do. iron, 4 pebbles, 1 knitted cuff, 1 acorn. Total weight, over 8 lbs.

THE

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JULY, 1873.

HOW THE SEA-DEPTHS ARE EXPLORED.

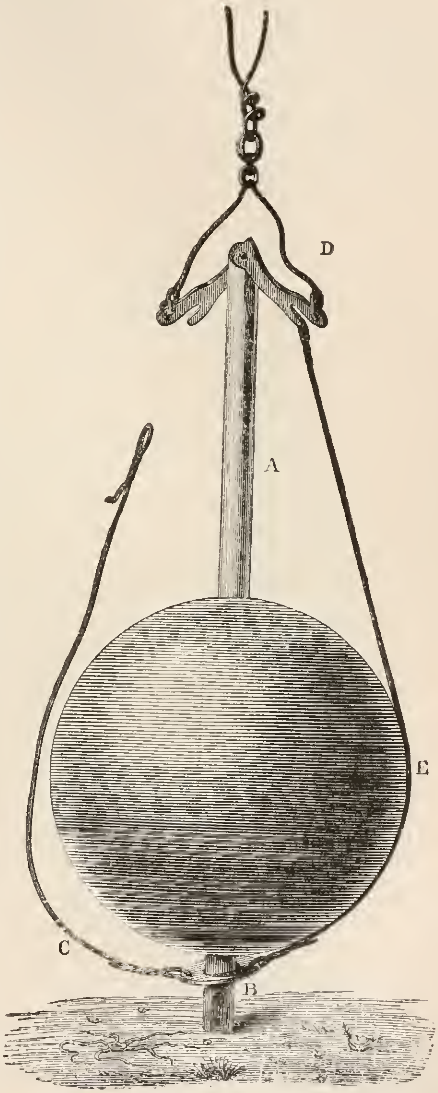
ONE of the most recent and impressive examples of the interaction of science and art by which knowledge is extended, and man's control over Nature increased, is furnished by the late remarkable investigations into the depths and life of the sea. The taking of soundings is, of course, as old as navigation, and is an indispensable portion of the mariner's art. The record of these soundings was embodied in charts by which sailors were guided in unknown waters. As commerce extended, such observations became more full, and resulted in systematic coast-surveys in which the depth of water, currents, magnetic conditions, temperatures, tides, and winds, were taken into account, and the knowledge thus accumulated gave rise at length to a great science—the Physical Geography of the Sea. About twenty-five years ago a new step was taken toward the extension of our knowledge of sea-depths. Science had given to the world the electric telegraph, and commerce demanded that it should be laid across the ocean. For this purpose the bed of the North Atlantic required to be carefully examined and mapped, and the configuration of the sea-bottom and the nature of its material determined. This gave a new impulse to the art of sea-sounding. The transatlantic cable was laid, got broken, and the end of it was then fished up from a depth of nearly two miles. A great victory was thus gained; the bottom of the sea was no longer inaccessible, and the possibility of its scientific exploration became established. Hitherto, sea observations had main reference to the advantages of navigation and commerce; but, from this time forward, the idea was entertained of pursuing the investigation in the interest of science alone. At the instance of the Royal Society, the British Admiralty, in 1868, granted a small government vessel, the gunboat Lightning, to Dr. William B. Carpenter and Prof. Wyville Thomson, to be used for dredging the bottom of the sea, and investigating its animal life. So promising were the results of this experiment, that a second expedition was arranged in 1869, and the government surveying-vessel Porcupine was assigned to the naturalists to carry on the work. This expedition was also so highly successful, that the ship Challenger has now started out on a four years' voyage around the world to carry out a comprehensive plan of deep-sea observations. We noticed very briefly last month the admirable work of Prof. Wyville Thomson on "The Depths of the Sea," giving a history of what has been lately done in the investigation of the subject. We propose now to lay Prof. Thomson's work under contribution for the benefit of our readers, and especially to give some account of the instruments of ocean-research, and the way the exploration is conducted.

It may be remarked, in passing, that, when the dredging of the deep seas was found to be feasible, questions of large scientific interest and moment, which had been hitherto regarded as inaccessible, were suddenly brought within the range of practical solution. It was a popular opinion, shared also by men of science, that the bottom of the sea was a dark and desolate waste, subject to such tremendous pressure as to render all life impossible. Prof. Thomson observes: "The enormous pressure at these great depths seemed at first sight alone sufficient to put any idea of life out of the question. There was a curious popular notion, in which I well remember sharing when a boy, that, in going down, the sea-water became gradually under the pressure heavier and heavier, and that all the loose things in the sea floated at different levels, according to their specific weight: skeletons of men, anchors, and shot, and cannon, and, last of all, the broad gold-pieces lost in the wreck of many a galleon on the Spanish Main, the whole forming a kind of false bottom to the ocean, beneath which there lay all the depth of clear, still water, which was heavier than molten gold. The conditions of pressure are certainly very extraordinary. At 12,000 feet a man would bear upon his body a weight equal to 20 locomotive-engines, each with a long goods-train loaded with pig-iron. We are apt to forget, however, that water is almost imcompressible, and that, therefore, the density of sea-water at a depth of 12,000 feet is scarcely appreciably increased."

Contrary to all anticipation, it was found that highly-organized representatives of all the invertebrate classes do live under these conditions of enormous pressure. The bottom of the ocean is, therefore, to be regarded as habitable, and is proved to be actually inhabited by numberless forms of animal life. A new world was thus opened to the naturalist, which, although difficult of access, was yet accessible and must be investigated. The pioneers in the exploration of course encountered very formidable obstacles; but the field was too vast and the promise too rich to be neglected, and how it was regarded by the devotees of research may be gathered from the following words of Dr. Thomson:

"Still the thing is possible, and it must be done again and again, as the years pass on, by naturalists of all nations working with improved machinery and with ever-increased knowledge. For the bed of the deep sea, the 140,000,000 square miles which we have now added to the legitimate field of natural-history research, is not a barren waste. It is inhabited by a fauna more rich and varied on account of the enormous extent of the area, and with organisms in many cases apparently even more elaborately and delicately formed, and more exquisitely beautiful in their soft shades of coloring and in the rainbow-tints of their wonderful phosphorescence, than the fauna of the well-known belt of shallow water, teeming with innumerable invertebrate forms, which fringes the land. And the forms of these hitherto unknown living beings, and their mode of life and their relations to other organisms, whether living or extinct, and the phenomena and laws of their geographical distribution, must be worked out."

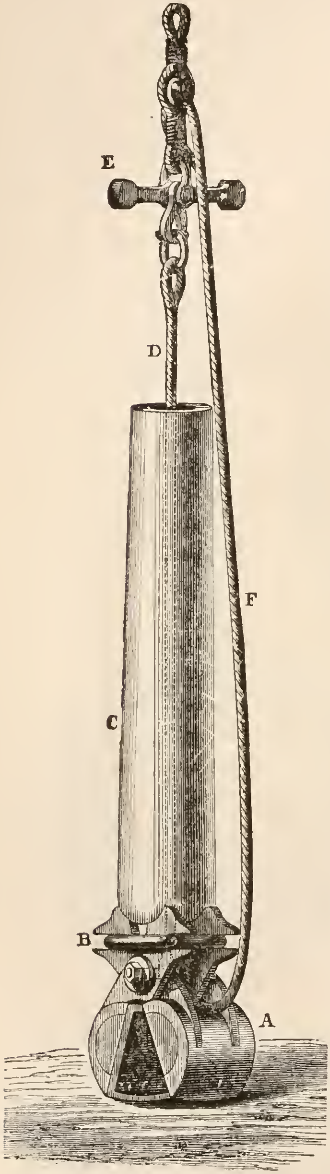
Fig. 1.



Brooke's Deep-Sea Sounding-Apparatus.

There are two principal operations in exploring the bottom of the ocean: first, sounding to ascertain depth; and, second, dredging to bring up materials. Although much ingenuity has been expended in devices to bring up samples of the sea-bottom by the sounding-apparatus, yet dredging contrivances are now mainly relied upon for that purpose. To determine the depth with a sounding-line, it is customary to graduate it by attaching slips of different-colored cloths or leather which mark it off into sections, and give the means of determining the distance to which the weight runs down. Another method of measuring the depth consisted in running down a weight attached to a line, which was cut at the surface as soon as the weight was supposed to have reached bottom, from a sudden change in the rate of running out, and the depth was then calculated by the length of cord left on the reel.

Fig. 2.

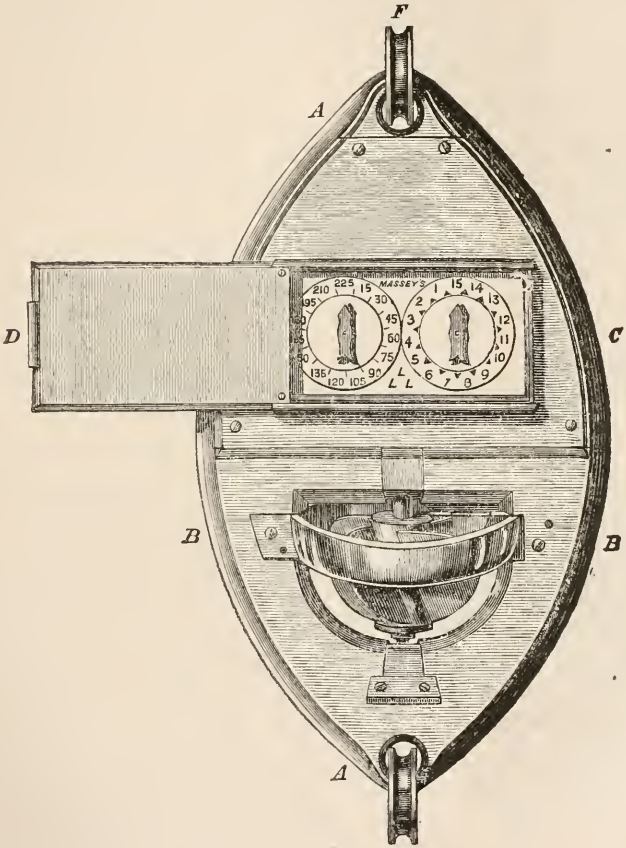


The Bull-dog Sounding-Machine.

The ordinary system of sounding fails at great depths, and cannot be depended upon for more than 6,000 feet. The weight is not sufficient to carry the line rapidly and vertically to the bottom, and, if a heavier weight be used, the line is in danger of breaking. No impulse is felt when the lead strikes the bottom, and the line goes on running out, and, if stopped, is liable to break. Sometimes the line is carried along by submarine currents, forming loops or bights, and it often continues to run out and coil itself in a tangled mass directly over the lead. These sources of error vitiate very deep soundings, so that the reports that have been made of measurements in the Atlantic of 39,000, 46,000, and 50,000 feet, without reaching bottom, are now regarded as exaggerations. In the last charts of the North Atlantic, on the authority of Rear-Admiral Richards, no soundings are entered beyond 24,000 feet, and very few beyond 18,000 feet.

The ordinary deep-sea lead, which is a prismatic block about two feet in length, and from 80 to 120 pounds in weight, has a simple provision for bringing up material from the bottom, which is called "arming"—that is, the lower end, which is slightly cupped, is covered with a thick coating of soft tallow. If it reaches the bottom, mud, shells, gravel, ooze, or sand, sticks to the tallow, and, when drawn up, affords a sample of the nature of the ground. As the interest in the bottom of the sea increased, there was a more eager curiosity to scrutinize the particles thus procured for chemical and microscopical examination, and it became desirable to devise means of bringing up larger amounts of matter. Many contrivances have been made for this purpose. Sir John Ross, in 1818, invented a machine for this purpose, called the "deep-sea clamm." A large pair of forceps were kept asunder by a bolt, and the instrument was so contrived that, on the bolt striking the ground, a heavy iron weight slipped down a spindle and closed the forceps, which retained within them a considerable quantity of the bottom, whether sand, mud, or small stones. By this arrangement Sir John Ross brought up six pounds of soft mud from a depth of 6,300 feet.

Fig 3.

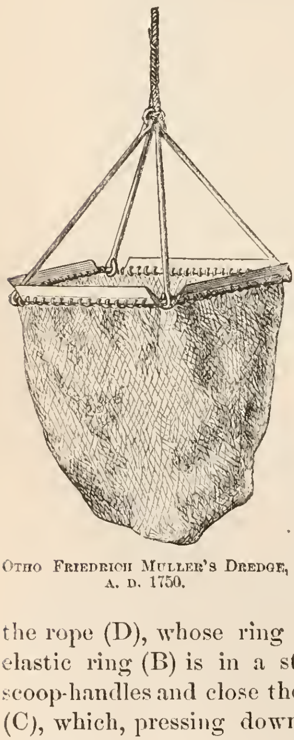


Massey's Sounding-Machine.

In the year 1854, J. M. Brooke, passed midshipman in the United States Navy, contrived the arrangement known as "Brooke's Deep-Sea Sounding-Apparatus," of which all the more recent contrivances have been to a great extent modifications and improvements, his fundamental principle being the detachment of a weight when the bottom is struck. The weight is a 64-pound shot (E, Fig. 1), cast with a hole through it. An iron rod (A B) passes through this hole, with an opening or chamber at the lower end "armed" with tallow. When the instrument strikes, the end of the rod is driven into the material of the bottom, which fills the chamber. At the same time a pair of hinged arms (D) at the top, which were upright in the descent, fall down and release the cord (C), which sustains the ball by a leather collar below. As the loops of the sling are relieved from the teeth of the arms, the rod slips through the hole in the shot, and comes up alone with its enclosed sample of sediment. The difficulty with this machine was the washing out of the material in the ascent. This was remedied by Commander Dayman, by adapting a valve, opening inward, to the terminal chamber of the rod.

In 1860 the assistant engineer of H. M. S. Bull-dog contrived a dredging-lead that combined the principle of Ross's clamm with the disengaging weight of Brooke. It is an ingenious and well-known machine, though hardly as simple as could be desired. Prof. Thomson thus describes it:

Fig. 4.



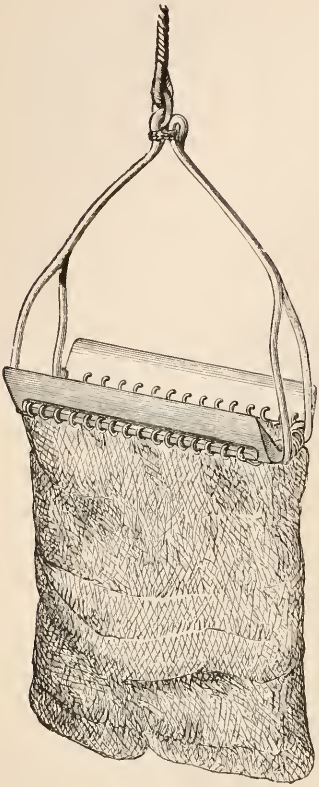
Otho Friedrich Muller's Dredge, A. D. 1750.

"A pair of scoops (A) close upon one another scissors-wise on a hinge, and have two pairs of appendages (B), which stand to the opening and closing of the scoops in the relation of scissor-handles. This apparatus is permanently attached to the sounding-line by the rope (F), which in the figure is represented as hanging loose, and which is fixed to the spindle on which the cups turn. Attached to the same spindle is the rope (D), which ends above an iron ring. E represents a pair of tumbler-hooks, fastened likewise to the end of the sounding-line; C a heavy leaden or iron weight, with a hole through it wide enough to allow the rope (D) with its loop and ring to pass freely; and B a strong India-rubber band, which passes round the handles of the scoops. In the figure the instrument is represented as it is sent down and before it reaches the bottom. The weight (C) and the scoops (A) are now suspended by the rope (D), whose ring is caught by the tumbler-hooks (E). The elastic ring (B) is in a state of tension, ready to draw together the scoop-handles and close the scoops, but it is antagonized by the weight (C), which, pressing down into a space between the handles, keeps them asunder. The moment the scoops are driven into the ground by the weight, the tension on the rope (D) is relaxed, the tumblers fall and release the ring, and the weight falls and allows the elastic band to close the scoops and keep them closed upon whatever they may contain; the rope (D) slips through the weight, and the closed scoops are drawn up by the rope (F)."

The attempt has been often made to measure the amount of vertical descent by self-registering machinery. Massey's sounding-machine is the best for this purpose, and operates upon a principle of screw-motion as it falls through the water. As represented in Fig. 3, two thimbles (F F) pass through the two ends of the heavy oval brass shield (A A). To the upper of these the sounding-line is attached, and to the lower the weight at about a yard from the machine. The screw-motion is communicated by a set of four brass vanes or rings (B), which are soldered obliquely to an axis in such a position that, as the machine descends, the axis revolves by the pressure of the water against the vanes. C represents the dial-plate as seen when the slide (D) is withdrawn. The revolving axis communicates its motion to the indices, which are so adjusted that the index on the right-hand dial passes through a division for every fathom of vertical descent whether quick or slow, and makes an entire revolution for 15 fathoms; while the left-hand index passes through a division on the circle for 15 fathoms, and makes an entire revolution during a descent of 225 fathoms. This instrument answers very well for accurate work in moderately deep water; but at extreme depths it has an uncertainty which seems to be shared by all contrivances involving metal wheel-work.

The main theatre of sounding operations has been the Atlantic Ocean, which, from its relation to the leading commercial nations, and for intercontinental telegraphic purposes, has been more carefully surveyed than any other great body of water. Open from pole to pole, participating in all conditions of climate, communicating freely with other seas, and covering 30,000,000 square miles, it is believed to represent general oceanic conditions, and to contain depths nearly, if not quite, as great as the other ocean-basins of the world, although but little is known, it is true, in this respect, of the Indian, Antarctic, and Pacific Seas. The general result of its soundings would indicate that the average depth of the Atlantic bed is not much more than 12,000 feet, and there seem to be few depressions deeper than 15,000 or 20,000 feet, a little more than the height of Mont Blanc. Dr. Thomson sums up the general results of the Atlantic soundings as follows: "In the Arctic Sea there is deep water, reaching to 9,000 feet to the west and south-west of Spitzbergen. Extending from the coast of Norway, and including Iceland, the Färöe Islands, Shetland and Orkney, Great Britain and Ireland, and the bed of the North Sea to the coast of France, there is a wide plateau, on which the depth rarely reaches 3,000 feet; but to the west of Iceland and communicating doubtless with the deep water in the Spitzbergen Sea, a trough 500 miles wide, and, in some places, nearly 12,000 feet deep, curves along the east coast of Greenland. This is the path of one of the great Arctic return-currents. After sloping gradually to a depth of 3,000 feet to the westward of the coast of Ireland in latitude 52°, the bottom suddenly dips to 10,000 feet at the rate of about 15 to 19 feet in the 100; and from this point to within about 200 miles of the coast of Newfoundland, when it begins to shoal again, there is a vast undulating submarine plain, averaging about 12,000 feet in depth below the surface—the 'telegraph plateau.'

Fig. 5.

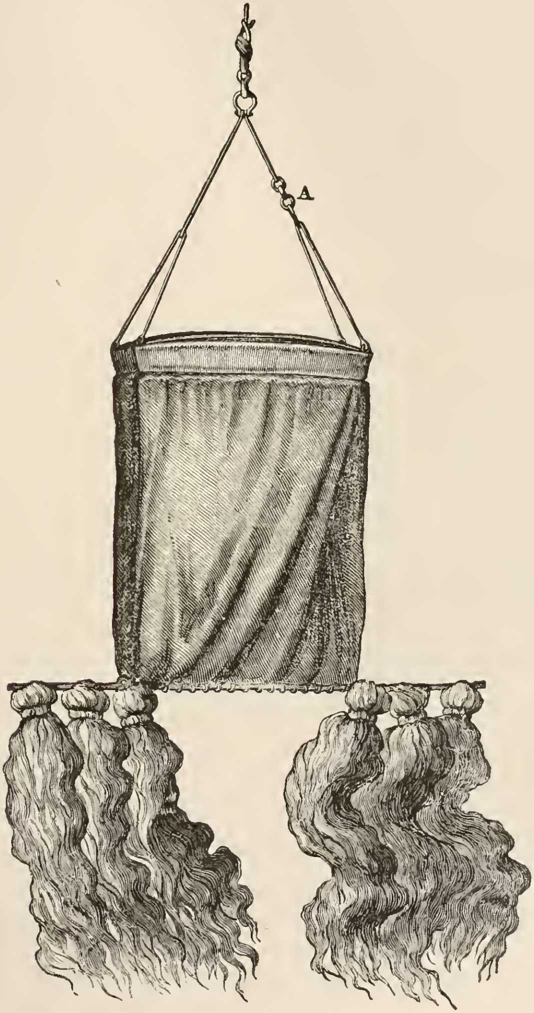


Ball's Dredge.

"A valley about 500 miles wide, and with a mean depth of 15,000 feet, stretches from off the southwest coast of Ireland, along the coast of Europe, dipping into the Bay of Biscay, past the Strait of Gibraltar, and along the west coast of Africa. Opposite the Cape de Verde Islands, it seems to merge into a slightly deeper trough, which occupies the axis of the South Atlantic, and passes into the Antarctic Sea. A nearly similar valley curves around the coast of North America, about 12,000 feet in depth, off Newfoundland and Labrador, and becoming considerably deeper to the southward, where it follows the outline of the coast of the States, and the Bahamas and Windward Islands, and finally joins the central trough of the South Atlantic off the coast of Brazil, with a depth of 15,000 feet."

Until within a hundred years but little was known of the living inhabitants of the deep sea, except the few objects that adhered to lead-lines, or were taken accidentally by fishermen in trawls and oyster-dredges; and, as odd things of no market value were generally thrown away, the knowledge from this source increased but slowly. The first dredge used by a naturalist to collect specimens from the sea-bottom was employed by Otho Friedrich Müller, who published a quaint book about it in 1779. His dredge was a square-mouthed bag (Fig. 4), and he does not appear to have used it beyond a depth of 180 feet. The dredges now used by naturalists are modifications of the oyster-dredge, which is described as a light frame of iron, about five feet long by a foot or so in width at the mouth, with a scraper like a narrow hoe on one side, and a suspending apparatus attached to the rope on the other. From the frame is suspended a bag, about two feet in depth, of wide netting or hempen cord. The naturalists' dredge has a scraper on each side, the bag is deeper, and the meshes so fine as to allow only the water to pass through.

Fig. 6.



Dredge with Hempen Tangles.

Fig. 5 represents the dredge devised by Dr. Ball, of Dublin, and which scraped the surface so perfectly that, when drawn along a drawing-room floor, it would pick up the pence that had been scattered before it. Dr. Thomson states that the most convenient size for dredging from a small boat, at a less depth than 600 feet, is a frame 18 inches long and five inches in width. The scrapers are three inches wide, and are so set that the distance across between their edges is 7½ inches.

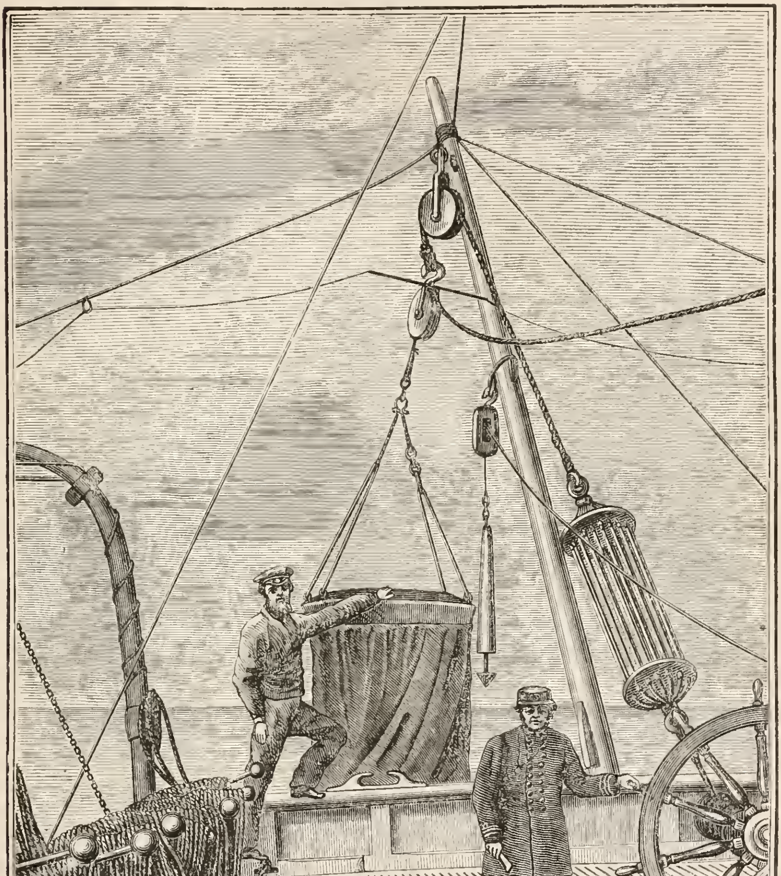
The dredge used for deep-sea work was larger, the frame being four feet six inches in length, and six inches wide at the throat or narrowest part. The weight of the frame was 225 lbs., but Dr. Thomson thinks it was too large and heavy. The dredge-bag was double, the outer being of strong twine netting lined within with "bread-bag," a light, open kind of canvas.

It was found by experience that very often, when nothing of interest was brought up within the dredge, many echinoderms, corals, and sponges, came to the surface, sticking to the outside of the bag, and even to the first few fathoms of the dredge-rope. This suggested the attachment of swabs, used for washing the decks, to the dredge. The tangled hemp turned out to be very efficient, picking up great numbers of objects that would not be otherwise secured. The bag took the mollusks, which, from their shelly forms, could not be otherwise obtained, while the echinoderms, corals, and sponges—bulky objects that could not readily enter the bag—were more easily caught by the swabs, although, unfortunately, it mutilated them, and brought them up in fragments. So important was this expedient, that a long iron bar was attached to the bottom of the dredge-bag, to which the hempen bundles were suspended, as shown in Fig. 6.

The arrangements for sounding and dredging from the Porcupine are fully described and illustrated in Prof. Thomson's work. The vessel was a 382-ton gunboat, with a steam-engine of 12 horse-power, stationed amidships, with drums of different sizes, from which lines were led fore and aft for working either at the bow or stern. Two powerful derricks were rigged for sounding and dredging, one over the stern and one over the port-bow. The block through which the sounding-line or dredging-rope passed was not attached directly to the derrick, but to a rope which passed through an eye at the end of the spar, and was fixed to a "bit," a piece of timber going through the deck. On a bight of this rope between the block and the "bit" was a piece of apparatus shown in Fig. 7, and called the "accumulator." This consisted of 30 or 40 strong India-rubber springs, working together, and its use was to yield by stretching, when, from any cause, as the pitching of the ship, there was an unusual strain upon the line. The dredge-rope of the Porcupine was of Russian hemp, 2½ inches in circumference, with a breaking strain of 2½ tons, and was 18,000 feet, or nearly 3½ miles long. A row of about 20 large iron pins, about 2½ feet in length, projected over one side of the quarter-deck, rising obliquely from the top of the bulwark. Upon these the rope was continuously coiled, as shown in the figure, which also represents the dredge in position for descent.

The method of dredging at a great distance is thus graphically described by Prof. Thomson, as it was performed in the Bay of Biscay, July 22, 1869. The depth was first accurately ascertained by sound-

Fig. 7.



The Stern Derrick of the Porcupine, showing the "Accumulator," the Dredge, and the Mode of stowing the Rope.

ing, and found to be 14,610 feet. "At 4.45 p. m. the dredge was let go, the vessel drifting slowly before a moderate breeze from the northwest. The 3,000 fathoms of rope were all out at 5.50 P. M. The diagram (Fig. 8) will give an idea of the various relative positions of the dredge and the vessel according to the plan of dredging adopted by Captain Calvert, which worked admirably, and which appears, in fact,

FIG. 8.

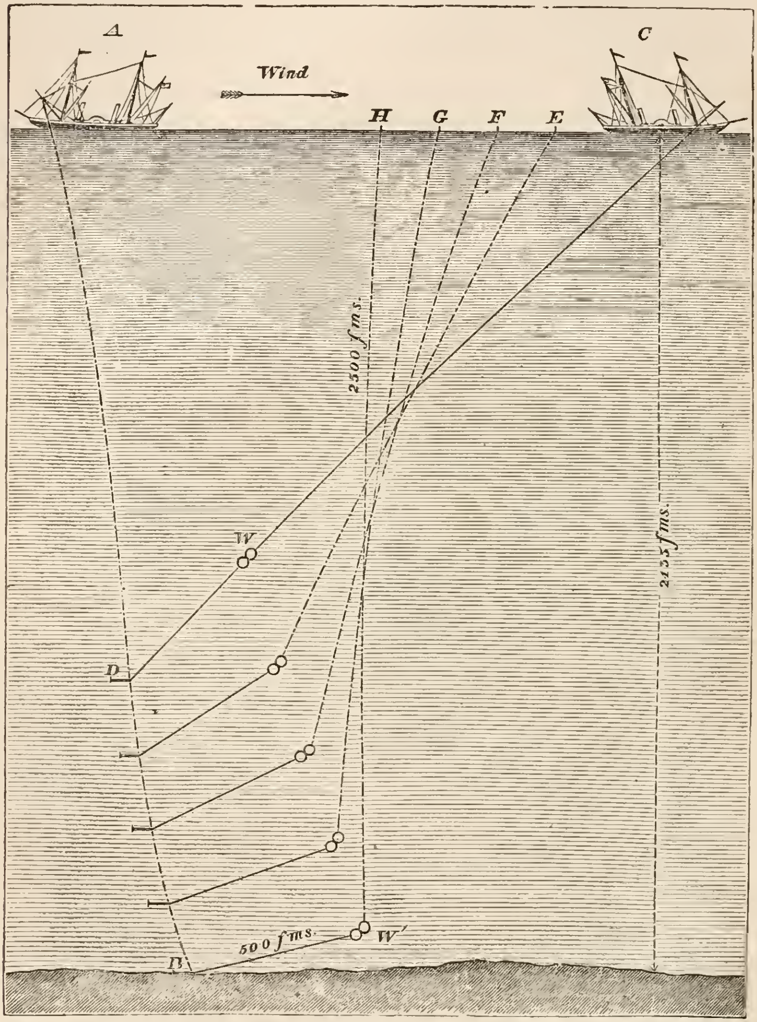


DIAGRAM OF THE RELATIVE POSITIONS OF THE VESSEL, THE WEIGHTS, AND THE DREDGE, IN DREDGING IN DEEP WATER.

to be the only mode that would answer for great depths. It represents the position of the vessel when the dredge is let go, and the dotted line (A B) the line of descent of the dredge rendered oblique by the tension of the rope. While the dredge is going down, the vessel drifts gradually to leeward; and, when the whole (say) 18,000 feet of rope are out, C W and D might represent respectively the relative positions of the vessel, the weight attached 3,000 feet from the dredge, and the dredge itself. The vessel now steams slowly to windward, occupying successively the positions E, F, G, H. The weight, to which the water offers but little resistance, sinks from W to W′, and the dredge and bag sink more slowly from D to B. The vessel is now allowed to drift back before the wind, from H toward C. The tension of the motion of the vessel, instead of acting immediately on the dredge, now drags forward the weight (W′), so that the dredging is carried on from the weight, and not directly from the vessel. The dredge is thus quietly pulled along, with its lip scraping the bottom in the attitude which it assumes from the centre of weight of its iron frame and arms. If, on the other hand, the weights were hung close to the dredge, and the dredge were dragged directly from the vessel, owing to the great weight and spring of the rope, the arms would be continually lifted up, and the lip of the dredge prevented from scraping. In very deep dredging this operation of stealing up to windward until the dredge-rope is nearly perpendicular, after drifting for half an hour or so to leeward, is usually repeated three or four times.

"At 8.50 P. M. we began to haul in. The donkey-engine delivered the rope at the rate of rather more than a foot per second without a single check. A few minutes before one A. M. the weights appeared, and, a little after one in the morning, eight hours after it was cast over, the dredge was safely hauled on deck, having in the interval accomplished a journey of upward of eight statute miles. The dredge contained $1\frac{1}{2}$ cwt. of very characteristic pale-gray Atlantic ooze." The total weight brought up by the engine was:

Weight of rope, reduced to $\frac{1}{4}$ in water	=	1,375 lbs.
Dredge and bag, " " "	=	275 "
Ooze brought up, " " "	=	168 "
Weight attached		224 "
		2,042

As an abundant and characteristic invertebrate life is now shown to exist at such great depths, it is inferred to extend to *all* depths; and thus the whole ocean-bed becomes in future the domain of the inquisitive naturalist. But, as Dr. Thomson remarks, little more can be said, for his work is all before him: "A grand new field of inquiry has been opened up, but its culture is terribly laborious. Every haul of the dredge brings to light new and unfamiliar forms—forms which link themselves strangely with the inhabitants of past periods in the earth's history; but as yet we have not the data for generalizing the deep-sea fauna, and speculating on its geological and biological relations; for, notwithstanding all our strength and will, the area of the bottom of the deep sea which has been fairly dredged may still be reckoned by the square yard."

THE PHYSIOLOGY OF DEATH.

By FERNAND PAPILLON.

TRANSLATED FROM THE FRENCH, BY A. R. MACDONOUGH.

OF old, the spoils of death fell to the anatomist's share, while the physiologist took for his part the phenomena of life. Now we submit the corpse to the same experiments as the living organism, and pry into the relics of death for the secrets of life. Instead of seeing in the lifeless body mere forms ready to dissolve and vanish, we detect in it forces and persisting activities full of deep instructiveness in their mode of working. As theologians and moralists exhort us to study the spectre of death face to face at times, and strengthen our souls by courageous meditation on our last hour, so medicine regards it as essential to direct our attention toward all the details of that mournful drama, and thus to lead us, through gloom and shadows, to a clearer knowledge of life. But it is only with respect to medicine in the most modern days that this is true.

Leibnitz, who held profound and admirable theories of life, had one of death also, which he has unfolded in a famous letter to Arnauld. He believes that generation is only the development and evolution of an animal already existing in form, and that corruption or death is only the reënvelopment or involution of the same animal, which does not cease to subsist and continue living. The sum of vital energies, consubstantial with monads, does not vary in the world; generation and death are but changes in the order and adjustment of the principles of vitality, simple transformations from small to great, and *vice versa.* In other words, Leibnitz sees everywhere eternal and incorruptible germs of life, which neither perish at all nor begin. What does begin and perish is the organic machine of which these germs compose the original activity: the elementary gearing of the machine is broken apart, but not destroyed. This is the earlier view held by Leibnitz. He has another, conceiving of generation as a progress of life through degrees; he can conceive of death also as a gradual regress of the same principle, that is to say, that in death life withdraws little by little, just as it came forward little by little in generation. Death is no sudden phenomenon, nor instantaneous evanishing—it is a slow operation, a "retrogradation," as the Hanoverian philosopher phrases it. When death shows to us, it has been a long time wearing away the organism, though we have not perceived it, because "dissolution at first attacks parts invisibly small." Yes, death, before it betrays itself to the eye by livid pallor, to the touch by marble coldness, before chaining the movements and stiffening the blood of the dying person, creeps with insidious secrecy into the smallest and most hidden points of his organs and his humors. Here it begins to corrupt the fluids, to disorganize the tissues, to destroy the equipoise and endanger the harmony. This process is more or less lingering and deceitful, and, when we note the manifest signs of death, we may be sure that the work lacked no deliberate preparation.

These ideas of Leibnitz, like most of the conceptions of genius, waited long after the time of their appearance for confirmation by demonstrative experiment. Before his day, bodies were dissected only for the sake of studying in them the conformation and normal arrangement of the organs. When this study was once completed, science took up the methodical inquiry into the changes produced in the different parts of the body by diseases. Not until the end of the eighteenth century did death in action become the subject of investigation by Bichat.

Bichat is the greatest of the physiological historians of death. The famous work he has left on this subject, his "Physiological Researches upon Life and Death," is as noteworthy for the grandeur of its general ideas, and its beauty of style, as for its precision of facts and nicety of experiment. To this day it remains the richest mine of recorded truths as to the physiology of death. Having determined the fact that life is seriously endangered only by alterations in one of the three essential organs, the brain, the heart, and the lungs, a group forming the vital tripod, Bichat examines how the death of one of these three organs assures that of the others, and in succession the gradual stoppage of all the functions. In our day, the advance of experimental physiology in the path so successfully traversed by Bichat, has brought to light in their minutest details the various mechanical processes of death, and, what is of far greater consequence, has disclosed an entire order of activities heretofore only suspected to be at work in the corpse. The theory of death has been built up by slow degrees along with that of life, and several practical questions that had remained in a state of uncertainty, such as that of the signs of real death, have received the most decisive answer in the course of these researches.

I.

Bichat pointed out that the complete life of animals is made up of two orders of phenomena, those of circulation and nutrition, and those that fix the relations of the living being with its environment. He distinguishes organic life from animal life, properly so called. Vegetables have only the former; animals possess both, intimately blended. Now, on the occurrence of death, these two sorts of life do not disappear at one and the same moment. It is the animal life that suffers the first stroke; the most manifest activities of the nervous system are those which come to a halt before all the rest. How is this stoppage brought about? We must consider separately the order of occurrences in death from old age, in that occasioned by disease, and in sudden death.

The man who expires at the close of a long decline in years, dies in detail. All his senses in succession are sealed. Sight becomes dim and unsteady, and at last loses the picture of objects. Hearing grows gradually insensible to sounds. Touch is blunted into dulness, odors produce but a weak impression, only taste lingers a little. At the same time that the organs of sensation waste and lose their excitability, the functions of the brain fade out little by little. Imagination becomes unfixed, memory nearly fails, judgment wavers. Further, motions are slow and difficult on account of stiffness in the muscles; the voice breaks; in short, all the functions of outward life lose their spring. Each of the bonds attaching the old man to existence parts by slow degrees. Yet the internal life persists. Nutrition still takes place, but very soon the forces desert the most essential organs. Digestion languishes, the secretions dry up, capillary circulation is clogged: that of the large vessels in their turn is checked, and, at last, the heart's contractions cease. This is the instant of death. The heart is the last thing to die. Such is the series of slow and partial deaths which, with the old man spared by disease, result in the last end of all. The individual who falls into the sleep of eternity in these conditions, dies like the vegetable which, having no consciousness of life, can have no consciousness of death. He passes insensibly from one to the other, and to die thus is to know no pain. The thought of the last hour alarms us only because it puts a sudden end to our relations with all our surroundings; but, if the feeling of these relations has long ago faded away, there can be no place for fear at the brink of the grave. The animal does not tremble in the instant before it ceases to be.

Unfortunately, death of this kind is very rare for humanity. Death from old age has become an extraordinary phenomenon. Most commonly we succumb to a disturbance in the functions of our vital system, which is sometimes sudden, sometimes gradual. In this case, as in the former one, we observe animal life disappearing first, but the modes of its conclusion are infinitely varied. One of the most usual is death through the lungs; as a result of pneumonia and different forms of phthisis, the oxidation of the blood becoming impossible on account of the disorganization of the pulmonary globules, venous blood goes back to the heart without gaining revivification. In the case of serious and prolonged fevers, and of infectious diseases, whether epidemic or otherwise, which are, characteristically, blood-poisonings, death occurs through a general change in nutrition. This is still more the fact as to death consequent upon certain chronic disorders of the digestive organs. When these are affected, the secretion of those juices fitted to dissolve food dries up, and these fluids go through the intestinal canal unemployed. In this case the invalid dies of real starvation. Hæmorrhage is one of the commonest causes of death. Whenever a great artery is opened from any cause, permitting the copious outflow of blood, the skin grows pale, warmth declines, the breathing is intermittent, vertigo and dimness of sight follow, the expression of the features changes, cold and clammy sweat covers part of the face and the limbs, the pulse gets gradually weaker, and, at last, the heart stops. Virgil describes hæmorrhage with striking fidelity in the story of Dido's death.

Sudden death, unconnected with outward and accidental causes, may occur in various ways. Very violent impressions on the feelings sometimes abruptly check the movements of the heart, and produce a mortal swoon. Instances are well known of many persons dying of joy—Leo X. is one—and of persons who succumbed to fear. In *foudroyant* apoplexy, if real death is not instantaneous, there is at least the sudden occurrence of the phenomena of death. The sufferer is plunged in profound sleep, called by physicians coma, from which wakening is impossible; his breathing is difficult, his eyes set, his mouth twisted and distorted. The pulsations of the heart cease little by little, and soon life utterly vanishes. The breaking of an aneurism very often occasions sudden death. Not less often the cause of death is found in what is called an embolism, that is, a check to the circulation by a clot of blood suddenly plugging up some important vessel. And there are also cases of sudden death still unaccounted for, in the sense that subsequent dissection discovers nothing that could explain the stoppage in the operations of life.

Death is usually preceded by a group of phenomena that has received the name of the death-agony. In most cases of disease the beginning of this concluding period is marked by a sudden improvement of the functions. It is the last gleam springing from the dying flame; but soon the eyes become fixed and insensible to the action of light, the nose grows pointed and cold, the mouth, wide open, seems to call for the air that fails it, the cavity within it is parched, and the lips, as if withered, cling to the curves of the teeth. The last movements of respiration are spasmodic, and a wheezing, and sometimes a marked gurgling sound, may be heard at some distance, caused by obstruction of the bronchial tubes with a quantity of mucus. The breath is cold, the temperature of the skin lowered. If the heart is examined, we note the weakening of its sounds and pulsations. The hand, placed in its neighborhood, feels no throb. Such is the physiognomy of a person in the last moments of death in the greater number of cases, that is, when death follows upon a period of illness of some duration. The death-struggle is seldom painful, and almost always the patient feels nothing of it. He is plunged into a comatose stupor, so that he is no longer conscious of his situation or his sufferings, and he passes insensibly from life to death, in a manner that renders it sometimes difficult to fix the exact instant at which a dying person expires. This is true, at least, in chronic maladies, and especially in those that consume the human body slowly and silently. Yet, when the hour of death comes for ardent organizations—for great artists, for instance, and they usually die young—there is a quick and sublime new burst of life in the creative genius. There is no better example of this than the angelic end of Beethoven, who, before he breathed out his soul, that tuneful monad, regained his lost speech and hearing, and spent them in repeating for the last time some of those sweet harmonies which he called his "Prayers to God." Some diseases, moreover, are most peculiarly marked by the gentleness of the dying agony. Of all the ills that cheat us while killing by pin-pricks, consumption is that which longest wears for us the illusive look of health, and best conceals the misery of living and the horror of dying. Nothing can be compared with that hallucination of the senses and that liveliness of hope which mark the last days of the consumptive. He takes the burning of his destroying fever for a healthful symptom, he forms his plans, and smiles calmly and cheerfully on his friends, and suddenly, some morrow of a quiet night, he falls into the sleep that never wakes.

If life is everywhere, and if, consequently, death occurs everywhere, in all the elements of the system, what must be thought of that point in the spinal marrow which a famous physiologist styled the vital knot, and in which he professed to lodge the principle of life itself? The point which Flourens regarded as this vital knot is situated nearly at the middle of the prolonged spinal cord—that is, the middle of that portion of the nerve-substance which connects the brain with the spinal marrow. This region, in fact, has a fine and dangerous excitability. A prick, or the penetration of a needle into it, is enough to cause the instant death of any animal whatever. It is the very means used in physiological laboratories to destroy life swiftly and surely in dogs. That susceptibility is explained in the most natural way. This spot is the starting-point of the nerves that go to the lungs; the moment that the slighest injury is produced in it, there follows a check on the movements of respiration, and ensuing death. This vital knot of Flourens enjoys no sort of special prerogative. Life is not more concentrated nor more essential in it than elsewhere; it simply coincides with the initial point of the nerves animating one of the organs indispensable to vitality, the organ of sanguification; and in living organisms any alteration of the nerves controlling a function brings a serious risk as to its complete performance. There is, therefore, no such thing as a vital knot, a central fire of life in animals. They are collections of an infinity of infinitely small living creatures, and each one of these microscopic living points is its own life-centre for itself. Each on its own account grows, produces heat, and displays those characteristic activities which depend upon its structure. Each one, by virtue of a preëstablished harmony, meets all the rest in the ways that they require; but, just as each lives on its own account, so on its account each dies. And the proof that this is so is found in the fact that certain parts taken from a dead body can be transferred to a living one without suffering any interruption in their physiological activity, and in the fact that many organs which seem dead can be excited anew, awakened out of their torpor, and animated to extremely remarkable vital manifestations. This subject we now proceed to consider.

II.

Death seems to be absolute from the instant that the pulsations of the heart are stopped without renewal, because, the circulation of the blood no longer proceeding, the nutrition of the organs becomes impossible, and nutrition is demanded for the maintenance of physiological harmony; but, as we have said above, there are a thousand little springs in the organism which keep up a certain degree of activity after the great main-spring has ceased to act. There is an infinite number of partial energies that outlive the destruction of the principal energy, and withdraw only by slow degrees. In cases of sudden death especially the tissues keep their peculiar vitality a very long time. In the first place, the heat declines only quite slowly, and the more so in proportion as death has been quick. For several hours after death the hair of the head and body, and the nails, continue to grow, nor does absorption either stop at once. Even digestion, too, keeps on. The experiment performed by Spallanzani to test this is very curious. He conceived the idea of making a crow eat a certain quantity of food, and killing it immediately after the meal. Then he put it in a place kept at the same temperature as that of a live bird, and opened it six hours later. The food was thoroughly digested.

Besides these general manifestations, the dead body is capable, during some continued time, of different kinds of activity. It is not easy to study these on the bodies of persons dying of sickness, because they are not permitted to be made the subject of anatomical examinations until twenty-four hours after death; but the bodies of beheaded criminals, which are given up to *savants* a few moments after their execution, can be of use in the investigation of what takes place immediately after the stopping of the living machine. If the heart is uncovered a few minutes after execution, pulsations are remarked which continue during an hour or longer, at the rate of forty to forty-five a minute, even after the removal of the liver, the stomach, and the intestines. For several hours the muscles retain their excitability, and undergo reflex contractions from the effect of pinching. M. Robin noted the following phenomenon in the case of a criminal an hour after his execution: "The right arm," to quote his description, "being placed obliquely extended at the side of the trunk, with the hand about ten inches away from the hip, I scratched the skin of the chest, at about the height of the nipple, with the point of a scalpel, over a space of nearly four inches, without making any pressure on the muscles lying beneath. We immediately saw the great pectoral muscle, then the biceps, then the anterior brachial, successively and quickly contract. The result was a movement of approach of the whole arm toward the trunk, with rotation inward of the limb, and half flexion of the forearm upon the arm, a true defensive movement, which threw the hand forward toward the chest as far as the pit of the stomach."

These spontaneous exhibitions of life in a corpse are trifles compared with those excited by means of certain stimulants, particularly of electricity. Aldini, in 1802, subjected two criminals, beheaded at Bologna, to the action of a powerful battery. Influenced by the current, the facial muscles contracted, producing the effect of horrid grimaces. All the limbs were seized with convulsive movements; the bodies seemed to feel the stir of resurrection, and to make efforts to rise. The springs of the system retained the power of answering the electric stimulus for several hours after beheading. A few years later, at Glasgow, Ure made some equally noted experiments on the body of a criminal that had remained more than an hour hanging on the gallows. One of the poles of a battery of 700 pairs having been connected with the spinal marrow below the nape of the neck, and the other brought in contact with the heel, the leg, before bent back on itself, was thrust violently forward, almost throwing down one of the assistants, who had hard work to keep it in place. When one of the poles was placed on the seventh rib, and the other on one of the nerves of the neck, the chest rose and fell, and the abdomen repeated the like movement, as takes place in respiration. On touching a nerve of the eyebrow at the same time with the head, the facial muscles contracted. "Wrath, terror, despair, anguish, and frightful grins, blended in horrible expression on the assassin's countenance."

The most remarkable instance of a momentary reappearance of vital properties, not in the whole organism, but in the head alone, is the famous experiment suggested by Legallois, and carried out for the first time in 1858 by M. Brown-Séquard. This skilful physiologist beheads a dog, taking pains to make the section below the point at which the vertebral arteries enter their bony sheath. Ten minutes afterward he sends the galvanic current into the different parts of the head thus severed from its body, without producing any result of movement. He then fits to the four arteries, the extremities of which appear in the cutting of the neck, little pipes connected by tubes with a reservoir full of fresh oxygenated blood, and guides the injection of this blood into the vessels of the brain. Immediately irregular motions of the eyes and the facial muscles occur, succeeded by the appearance of regular harmonious contractions, seeming to be prompted by the will. The head has regained life. The motions continue to be performed during a quarter of an hour, while the injection of blood into the cerebral arteries lasts. On stopping the injection, the motions cease, and give place to the spasms of agony, and then to death.

Physiologists asked whether such a momentary resurrection of the functions of life might not be brought about in the human subject—that is, whether movement might not be excited and expression re-animated by injecting fresh blood into a head just severed from a man's body, as in M. Brown-Séquard's experiment. It was suggested to try it on the heads of decapitated criminals, but anatomical observations, particularly those of M. Charles Robin, showed that the arteries of the neck are cut by the guillotine in such a way that air penetrates and fills them. It follows that it is impracticable to inject them with blood that can produce the effects noted by M. Brown-Séquard. Indeed, we know that blood circulating in the vessels becomes frothy on contact with air, and loses fitness for its functions. M. Robin supposes that the experiment in question could be successful only if made upon the head of a man killed by a ball that should strike below the neck; in that case it would be possible to effect such a section of the arteries that no entrance of air would occur, and, if the head were separated at the place pointed out by M. Brown-Séquard, those manifestations of function remarked in the dog's head would probably be obtained by the injection of oxygenated blood. M. Brown-Séquard is convinced that they might be obtained, if certain precautions were observed, even with the head of a decapitated criminal; and, so strong is his conviction, that, when it was proposed to him to try the experiment—that is, to perform the injection of blood into the head of a person executed—he refused to do so, not choosing, as he said, to witness the tortures of this fragment of a being recalled for an instant to sensibility and life. We understand M. Brown-Séquard's scruples, but it is allowable to doubt whether he would have inflicted great suffering on the head of the subject; at most, he would only have aroused in it a degree of very dim and uncertain sensibility. This is easily explained. In life, the slightest perturbation in the cerebral circulation is enough to prevent thought and sensation utterly. Now, if a few drops of blood too much or too little in the brain of an animal in full health suffice to alter the regularity of its psychical manifestations, much more certainly will the completeness of the brain's action be deranged if it is awakened by an injection of foreign blood, a forcible entry too, which, of necessity, cannot cause the blood to circulate with suitable pressure and equipoise.

Corpse-like rigidity is one of the most characteristic phenomena of death. This is a general hardening of the muscles, so great that they lose the property of extension till even the joints cannot be bent; this phenomenon begins some hours after death. The muscles of the lower jaw are the first to stiffen; then rigidity invades in succession the abdominal muscles, those of the neck, and at last the thoracic ones. This hardening takes place through the coagulation of the half-fluid albuminoid matter which composes the muscular fibres, as the solidification of the blood results from coagulation of its fibrine. After a few hours the coagulated musculine grows fluid again, rigidity passes away, and the muscles relax. Something not dissimilar takes place also in the blood. The globules change, lose shape, and suffer the beginning of dissociation. The agents of putrefaction, vibrios and bacteria, thus enter upon their great work by insidiously breaking up the least seen parts.

At last, when partial revivals are no longer possible, when the last flicker of life has gone out and corpse-like rigidity has ceased, a new work begins. The living germs that had collected on the surface of the body and in the digestive canal develop, multiply, pierce into all the points of the organism, and produce in it a complete separation of the tissues and humors; this is putrefaction. The moment of its appearance varies with the causes of death and the degree of outward temperature. When death is the result of a putrid malady, putrefaction begins almost immediately when the body has grown cold. It is the same when the atmosphere is warm. In general, in our climates, the work of decomposition becomes evident after from thirty-eight to forty hours. Its first effects are noticeable on the skin of the stomach; this takes on a greenish discoloration, which soon spreads and covers successively the whole surface of the body. At the same time the moist parts, the eye, the inside of the mouth, soften and decay; then the cadaverous odor is gradually developed, at first faint and slightly fetid, a mouldy smell, then a pungent and ammoniacal stench. Little by little the flesh sinks in and grows watery; the organs cease to be distinguishable. Every thing is seized upon by what is termed putridity. If the tissues are examined under the microscope at this moment, we no longer recognize any of the anatomical elements of which the organic fabric is made up in its normal state. "Our flesh," Bossuet exclaims in his funeral-sermon on Henrietta of England, "soon changes its nature, our body takes another name; even that of a corpse, used because it still exhibits something of the human figure, does not long remain with it. It becomes a thing without a shape, which in every language is without a name." When structure has wholly disappeared, nothing more remains but a mixture of saline, fat, and proteic matters, which are either dissolved and carried away by water, or slowly burned up by the air's oxygen, and transmuted into new products, and the whole substance of the body, except the skeleton, returns piecemeal to the earth whence it came forth. Thus the ingredients of our organs, the chemical elements of our bodies, turn to mud and dust again. From this mud and this dust issue unceasingly new life and energetic activity; but a clay fit for the commonest uses may also be got from it, and, in the words of Shakespeare's *Hamlet*, the dust of Alexander or Cæsar may plug the vent of a beer-cask, or "stop a hole to keep the wind away." These "base uses," of which the Prince of

Denmark speaks to *Horatio*, mark the extreme limits of the transformation of matter. In any case the beings of lowest order that toil and engender in the bosom of putrefaction are really absorbing and storing away life, since without their aid the corpse could not serve as nutriment to plants, which in their turn are the necessary reservoir whence animality draws its sap and strength. It is in this sense that Buffon's doctrine of organic molecules is a true one.

Death is the necessary end of all organic existence. We may hope more or less to set at a distance its inevitable hour, but it would be madness to dream of its indefinite postponement in any species whatsoever. No doubt there is no contradiction in conceiving of a perfect equilibrium between assimilation and disassimilation, such that the system would be maintained in immortal health. In any case, no one has yet even gained a glimpse of the modes of realizing such an equilibrium, and death continues, till further orders, a fixed law of Fate. Still, though immortality for a complete organism seems chimerical, perhaps it is not the same with the immortality of a separate organ in the sense we now explain. We have already alluded to the experiments of M. Paul Bert on animal-grafting. He has proved that, on the head of a rat, certain organs of the same animal—as the tail, for instance—may be grafted. And this physiologist asks himself the question, whether it would not be possible, when a rat provided with such an appendage draws near the close of his existence, to remove the appendage from him, and transplant it to a young animal, which in his turn would be deprived of the ornament in the same way in his old age in favor of some specimen of a new generation, and so on in succession. This tail, transplanted in regular course to young animals, and imbibing at each transference blood full of vitality, perpetually renewed, yet ever remaining the same, would thus escape death. The experiment, delicate and difficult, as we well see, was yet undertaken by M. Bert, but circumstances did not allow it to be prolonged for any considerable time, and the fact of the perpetuity of an organ, periodically rejuvenated, remains to be demonstrated.

III.

Real death, then, is characterized by the positive ceasing of vital properties and functions both in the organic or vegetative life, and in the animal life, properly so termed. When animal life disappears without any interruption occurring in organic life, the system is in a state of seeming death. In this state the body is possessed by profound sleep quite similar to that of hibernating animals; all the usual expressions and all signs of internal activity have disappeared, and give place to invincible torpor. The most powerful chemical stimulants exert no control over the organs, the walls of the chest are motionless; in short, seeing the body presenting this appearance, it is impossible not to think of it as dead. There are quite numerous states of the organism which may thus imitate death more or less closely; the commonest one is that of fainting. In this case neither sensation nor movements of circulation or respiration are any longer perceptible; the warmth is lowered, the skin pallid and colorless. Instances of hysteria are cited in which the attack has been prolonged for several days, attended with fainting. In this strange condition all physiological manifestations remain suspended; yet they are not, as it was long supposed, suspended absolutely. M. Bouchest has proved that, in the gravest cases of fainting, the pulsations of the heart continue, weaker and rarer, and harder to be heard than in normal life, but clearly distinguishable when the ear is laid on the precordial region. On the other hand, the muscles retain their suppleness and the limbs their pliability.

Asphyxia, which properly is suspension of breathing, and consequently of the blood's revivification, sometimes passes into a serious fainting condition followed by seeming death, from which the sufferer recovers after a period of varying length. This state may be induced either by drowning or by inhaling a gas unfit for respiration, such as carbonic acid in deep wells, emanations from latrines, or the choke-damp of mines, or by suffocation. In 1650 a woman named Ann Green was hanged at Oxford. She had been hanging for half an hour, and several people, to shorten her suffering, had pulled her by the feet with all their strength. After she was placed in her coffin it was observed that she still breathed. The executioner's assistants attempted to end her existence, but, thanks to the help of physicians, she came back to life, and continued to live some time afterward. Drowning occasions an equally deep insensibility, during which, very singularly, the psychical faculties retain some degree of activity. Sailors, after timely resuscitation from drowning, declare that, while under water, they had returned in thought to their families, and sadly fancied the grief about to be caused by their death. After a few minutes of physical rest, they suffered violent colic of the heart, which seemed to twist itself about in their chests; afterward this anguish was followed by utter annihilation of consciousness. It is very difficult, moreover, to determine how long apparent death may be protracted in an organism under water. It varies greatly with temperaments.

In the islands of the Greek archipelago, where the business of gathering sponges from the bottom of the sea is pursued, children are not allowed to drink wine until, by practice, they have grown accustomed to remain a certain time under water. Old divers of the archipelago say that the time to return and take breath at the surface is indicated to them by painful convulsions of the limbs, and very severe contractions in the region of the heart. This power of enduring asphyxia for some time, and resisting by force of will the movements of respiration, has been remarked under other circumstances. The case of a Hindoo is mentioned, who used to creep into the palisaded enclosures used for bathing, in the Ganges, by the ladies of Calcutta, seize one of them by the legs, drown her, and rob her of her rings. It was supposed that a crocodile carried her off. One of his intended victims succeeding in escaping, the assassin was seized and executed in 1817. He confessed that he had practised the horrible business for seven years. Another instance is that of a spy, who, seeing preparations making for his execution, endeavored to escape it by feigning death. He held his breath, and suspended all voluntary motions for twelve hours, and endured all the tests applied to him to put the reality of his death beyond doubt. Anæsthetics, too, like chloroform and ether, sometimes produce stronger effects than the surgeons using them desire, and occasion a state of seeming death instead of temporary insensibility.

It is easy to recall persons to life who are in a state of seeming death; it is only needful to stimulate powerfully the two mechanical systems that are more or less completely suspended in action, namely those of respiration and circulation. Such movements are communicated to the frame of the chest, that the lungs are alternately compressed and dilated. A sort of shampooing is applied over the whole body, which restores the capillary circulation; chemical stimulants, such as ammonia or acetic acid, are brought under the patient's nostrils. This is the mode of treatment for drowned persons, whose condition is brought on by ceasing to breathe the air, not by taking in too much water. A very effective method in cases of apparent death, caused by inhaling a poisonous gas, such as carbonic acid or sulphuretted hydrogen, consists in making the patient draw in large quantities of pure oxygen. And, again, it has very lately been proposed, as Hallé suggested without success early in this century, to adopt the use of strong electric currents for stimulating movement in persons who are in a state of syncope.

In all the cases of seeming death we have just mentioned, one mark of vitality persistently remains, that is, pulsation of the heart. Its throbs are less strong and frequent, but they continue perceptible on auscultation. They are regularly discernible in the deepest fainting-fits, in the various kinds of asphyxia, in poisonings by the most violent narcotics, in hysteria, in the torpor of epilepsy, in short, in the most diverse and protracted states of lethargy and seeming death.

Yet, this result, now a practical certainty, was unknown to physicians of old, and it cannot be denied that, in former times, seeming death was quite often mistaken for true death. The annals of science have recorded a certain number of errors of this kind, many of which have resulted in the interment of unfortunate wretches who were not dead. And for one of these mistakes that chance has brought to light either too late, or in time for the rescue, even then, of the victim, how many are there, particularly in times of ignorance and carelessness, that no one has ever known! How many live men have only given up their last breath after a vain struggle to break out of their coffin! The facts collected by Bruhier and Lallemand in two works that have become classic compose a most mournful and dramatic history. These are some of its episodes, marked by the strange part that chance plays in them. A rural guard, having no family, dies in a little village of Lower Charente. Hardly grown cold, his body is taken out of bed, and laid on a straw ticking covered with a coarse cloth. An old hired woman is charged with the watch over the bed of death. At the foot of the corpse were a branch of box, put into a vessel filled with holy water, and a lighted taper. Toward midnight the old watcher, yielding to the invincible need of sleep, fell into a deep slumber. Two hours later she awoke surrounded by flames from a fire that had caught her clothes. She rushed out, crying with all her might for help, and the neighbors, running together at her screams, saw in a moment a naked spectre issue from the hut, limping and hobbling on limbs covered with burns. While the old woman slept, a spark had probably dropped on the straw bed, and the fire it kindled had aroused both the watcher from her sleep and the guard from his seeming death. With timely assistance he recovered from his burns, and grew sound and well again.

On the 15th of October, 1842, a farmer in the neighborhood of Neufchâtel, in the Lower Seine, climbed into a loft over his barn to sleep, as he usually did, among the hay. Early the next day, his customary hour of rising being past, his wife, wishing to know the cause of his delay, went to look for him, and found him dead. At the time of interment, more than twenty-four hours after, the bearers placed the body in a coffin, which was closed, and carried it slowly down the ladder by which they had gained the loft. Suddenly one of the rounds of the ladder snapped, and the bearers fell together with the coffin, which burst open with the shock. The accident, which might have been fatal to a live man, was very serviceable to the dead one, who was roused from his lethargy by the concussion, returned to life, and hastened to get out of his shroud with the assistance of those of the bystanders who had not been frightened away by his sudden resurrection. An hour later he could recognize his friends, and felt no uneasiness except a slight confusion in his head, and the next day was able to go to work again. At about the same time a resident of Nantes gave up life after a long illness. His heirs made arrangements for a grand funeral, and, while the performance of a requiem was going on, the dead man returned to life and stirred in the coffin, that stood in the middle of the church. When carried home, he soon regained his health. Some time afterward, the *curé*, not caring to be at the trouble of the burial ceremonies for nothing, sent a bill to the ex-corpse, who declined to pay it, and referred the *curé* to the heirs who had given orders for the funeral. A lawsuit followed, with which the papers of the day kept the public greatly amused. A few years ago Cardinal

Donnet, in the Senate, told his own story of the circumstances under which he narrowly escaped being buried alive.

Besides these instances of premature burial in which the victim escaped the fearful consequences of the mistake made, others may be cited in which the blunder was discovered only too late. Quite a number of such cases are known, some of which are told with details too romantic to entitle them to implicit belief, while, however, many of them show unquestionable signs of authenticity. There long prevailed a tradition, not easily traceable to any source, which attributed the death of the Abbé Prévost to a mistake of this kind. All his biographers relate that the famous author of "Manon Lescaut," falling senseless from the effect of a rush of blood, in the heart of the forest of Chantilly, was supposed to be dead; that then the surgeon of the village having made an incision into his stomach, by direction of the magistrate, to ascertain the cause of death, Prévost uttered a cry, and did then die in earnest. But it has since been proved that the story is imaginary, and that it was made up after Prévost's death; nor do any of the necrological accounts published at the time refer it to the consequences of a premature autopsy. Though the account of Prévost dissected alive seems doubtful, that is not the case with the story told with regard to an operation by the famous accoucheur, Philip Small. A woman, about to be confined, fell into a state of seeming death. Small relates that when he was summoned to perform the Cesarean operation, the by-standers, convinced that the woman was dead, urged him to proceed with it. "I supposed so, too," he says, "for I felt no pulse in the region of the heart, and a glass held over her face showed no sign of respiration." Then he plunged his knife into the body, and was cutting among the bleeding tissues, when the subject awoke from her lethargy.

We cite some still more startling instances. Thirty years ago, a resident of the village of Eymes, in Dordogne, had been suffering for a long time from a chronic disorder of little consequence in itself, but marked by the distressing symptom of constant wakefulness, which forbade the patient any kind of rest. Worn out with this condition, he consulted a doctor, who prescribed opium, advising great caution in its use. The invalid, possessed with that common-enough notion that the efficacy of a drug is proportioned to its quantity, took at one time a dose sufficient for several days. He soon fell into a deep sleep, which continued unbroken for more than twenty-four hours. The village doctor, being summoned, finds the body without warmth, the pulse extinct, and, on opening the veins of both arms in succession, obtains but a few drops of thick blood. The day after, they prepared for his burial. But, a few days later, closer inquiry revealed the imprudence the poor wretch had committed in taking an excessive quantity of the prescribed narcotic. The report spreading among the villagers, they insist on his disinterment, which is allowed. Gathering in a crowd, at the cemetery, they take up the coffin, open it, and are met by a horrible sight. The miserable man had turned over in his coffin, the blood gushing from the two opened veins had soaked the shroud; his features were frightfully contorted, and his convulsed limbs bore witness to the cruel anguish that had preceded death. Most of the facts of this kind are of rather remote date. The latest instances have happened in the country, among an ignorant population, usually in neighborhoods where no physician was called on to ascertain the decease, that is, to distinguish the cases of seeming death from those of true death.

How, then, can we certainly know apparent from real death? There is a certain number of positive signs of death; that is to say, signs which, when absolutely discerned, leave no room for mistake. Yet some physicians, and many people who know nothing of science, are still so doubtful about the certainty of these signs as to wish that physiology could detect others of a more positive character. A zealous philanthropist, quite lately, gave a sum for a prize of twenty thousand francs to the discoverer of an infallible sign of death. Doubtless, the intention is excellent, but we are safe henceforward in regarding the sexton's work without alarm; the signs already known are clear enough to prevent any mistake, and to make the fatal risk of premature burial impossible.

We must point out, in the first place, the immediate signs of death. The first, and the most decisive, is the absolute stoppage of the heart's pulsations, noted for a duration of at least five minutes, not by the touch, but by the ear. "Death is certain," says the reporter of the commission named in 1848, by the Academy of Sciences, to award the prize of competition as to the signs of true death, "when positive cessation of pulsations of the heart in the subject has been ascertained, which is immediately followed, if it has not been preceded, by cessation of respiration, and of the functions of sensation and motion." The remote signs equally deserve attention. Of these, three are recognized: corpse-like rigidity, resistance to the action of galvanic currents, and putrefaction. As we have already seen, rigidity does not begin till several hours after death, while general and complete disappearance of muscular contractility, under the stimulus of currents, and, last of all, putrefaction, are only manifest at a still later period. These remote signs, particularly the last, have this advantage, that they may be ascertained by those unacquainted with medicine, and it is very well to pay some attention to them in countries where physicians are not charged with the verification of the disease, but they are of no importance wherever there are doctors to examine the heart with instruments, and to decide promptly and surely upon the death, from the complete stoppage of pulsation in that organ. At the beginning of the century, Hufeland, and several other physicians, convinced that all the signs of death then known were uncertain, except putrefaction, proposed and obtained, in Germany, the establishment of a certain number of mortuary houses, intended to receive, and keep for some time, the bodies of deceased persons. During the whole existence of these establishments, not one of the bodies transported into those asylums has been known to return to life, as the authentic declarations of the attendant doctors agree. The usefulness of such mortuary houses is still more questionable in our time, when we have a positive and certain means of recognizing real death. Those police regulations that forbid autopsies and interments until the full term of delay for twenty-four hours, measured from the declaration of death, still remain prudent precautions, but they do not lessen at all the certainty of that evidence furnished by the stopping of the heart. When the heart has definitely ceased to beat, then resurrection is no longer possible, and the life which deserts it is preparing to enter upon a new cycle.

Hamlet, in his famous soliloquy, speaks of "that undiscovered country from whose bourn no traveller returns," and mournfully asks, what must be the dreams of the man to whom death has opened the portals of those gloomy regions. We can give no clearer answer, in the name of physiology, than Shakespeare's prince gives. Physiology is dumb as to the destiny of the soul after death; of that it teaches, and it can teach us, nothing. It is plain, and it would be childish to deny it, that any psychical or sentient manifestation, and any concrete representation of the personality, are impossible after death. The dissolution of the organism annihilates surely, and of necessity, the functions of sensation, motion, and will, which are inseparable from a certain combination of material conditions. We can feel, move, and will, only so far as we have organs for reception, transmission, and execution. These assurances of science are above discussion, and should be accepted without reserve. Do they tell us any thing of the destiny of the psychical principles themselves? Again we say, No, and for the very simple reason that science does not attain to those principles; but metaphysics, which does attain to them, authorizes us, nay, further, compels us to believe that they are immortal. They are immortal, as the principles of motion, the principles of perception, all the active unities of the world, are immortal. What is the general characteristic of those unities? It is that of being simple, which means being indestructible, which means being in harmonious mutual connection, after such a manner that each one of them perceives the infinite order of the other. If this connection did not exist, there would be no world. What is the characteristic of the psychical unities more especially? It is that of having, besides the consciousness of such perception, the feeling also of the relations that bind the whole together, and those faculties, more or less developed, which that consciousness and that perception imply. But why should these unities be any more perishable than the others? Why, if all these forces, all these activities, are eternal, should those alone not possess eternity which have this high privilege, that of knowing the infinite relations which the others sustain without knowing that they do so?

To form a conception of the immortality of the soul, then, we must place ourselves at that point of view to which men rarely and hardly rise, of the simplicity and the indefectibility of all those principles of force that fill the universe. We must train ourselves to understand that what we see is nothing in comparison with what we do not see. The whole force, the whole spring, of the most complex movements, the most magnificent phenomena of Nature, and the most subtle operations of life, thought included, proceed from the infinite commingling of an infinity of series of invisible and unextended principles, whose activities ascend in the scale of perfection from simple power of movement up to supreme reason. Human personality, such as we see and know it, is only a coarse and complex result from those of these primitive activities which are the best and deepest thing in us. It is not that personality which is immortal—that is no more immortal than the motive force of a steam-engine is, or the electricity of a voltaic battery, although movement and electricity are of themselves indestructible. It is not that personality which can aspire to a home in the bosom of God. Our true personality, our real *I*, that which may without illusion count on a future life, is unity released from every material bond, and all concrete alloy; it is that force, necessarily pure, which has a more or less clear consciousness of its own relations with the infinity of like unities, and which more or less draws near to them by thought and by love. It is beyond our power to conceive what will become of that unity when, quitting its prison of flesh, and soaring into the ideal ether, it will no longer have organs with which to act; but what we can affirm is that, precisely by reason of this freedom, it will rise to a clearer knowledge of all that it had only known obscurely, and to a purer love of what it had adored only through the veil of sense. And this certainty, which is the ennobling and elevating force of life, is also the consolation for death.—*Revue des Deux Mondes.*

NATURE AND ORIGIN OF THE DRIFT-DEPOSITS OF THE NORTHWEST.

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II. *Origin of the Drift.*

THE first records of exact observations pertaining to the drift seem to have been made in the first quarter of the present century, and are wholly confined to the appearances and positions of the bowlders, or "travelled rocks," that constitute a striking object to the scientific observer throughout the northern portions of Europe and America. In 1819 the memoirs of the Wernerian Society of Edinburgh announced the transportation by ice of a large piece of conglomerate 4 × 6 × 8 feet a distance of 260 yards in one night. It was deposited in the sands on the shores of a little bay on the Mersey Firth.

A similar account is published in the *American Journal of Science and Arts*, 1822, as occurring at Salisbury, Connecticut.

After the year 1820, exact observations were stimulated in this country by the publication of the *American Journal of Science and Arts*, which from time to time called attention to the various phenomena of the drift. The earliest investigations of note were made by De Saussure, Pallas, and De Luc, on the Continent of Europe, and by Sir James Hall in Scotland. These observers coincided in the opinion that the existence of the "travelled rocks" must be explained by the occurrence of devastating currents of water, or *débâcles*, from the north, which transported them from their original places. This theory was advocated, sometimes with slight modifications, by the revered Dr. Edward Hitchcock, of Massachusetts; by Dr. Benjamin Silliman, of Connecticut; by Dr. Hildreth, of Ohio; Lapham, of Wisconsin; J. N. Nicollet, of Minnesota; and by Von Buch, Studer, Buckland, and De la Beche, of Europe. Von Buch, seeing that one *débâcle*, proposed by De Saussure, would not account for all the phenomena, supposed there were several. De la Beche believed this vast inundation from the north was the immediate result of a sudden upheaval of the polar regions, turning the waters of the Arctic Ocean southward with great violence. This cause was also accepted by Prof. Buckland and Dr. Silliman. This theory is the same as that known as *diluvion*. Hence the groovings on the rocks were first known as *diluvial* marks.

Contemporary with the *débâcle* theory was that of Chabrier, who believed the bowlders came from the atmosphere. This theory seems not to have met with very much countenance, and soon ceased to be regarded.

In 1828 Peter Dobson, of Connecticut, proposed the germ of what became an important and long-lived theory, viz., that floating ice, in the form of vast sheets, carried great quantities of gravel and stones, and distributed them wherever they were stranded. This suggestion, aided by the quick indorsement of Sir R. I. Murchison, grew into that known as the iceberg theory, which survives to the present day. This last necessitates the submergence of the continent beneath the quiet waters of the ocean, and here diverges from the *débâcle* theory which requires turbulent waters. The iceberg theory received many prominent and able advocates. Among them may be named Sir Charles Lyell, Sir Roderick I. Murchison, Peter Dobson, John L. Hays, C. T. Jackson, Sedgwick, of England; W. C. Redfield, of New England; Prof. Mather, of Ohio; Dawson, of Canada; and a great many others.

Before, however, the iceberg theory had grown into prominence, Mr. De Kay, of New York, proposed another, which at least has the advantage of allowing the continent to stand still instead of sinking it several thousand feet below the ocean-level.

Mr. De Kay claimed that the bowlders originated at or near the places in which they now lie; that they are the remains of ancient peaks of primitive rock that have since been demolished by earthquakes and by atmospheric forces, the sites covered by detritus, and concealed from the observer. This was announced in 1828, but it made no headway, probably from the fact that these bowlders lie on the surface not only where primitive rocks abound, but also over broad areas where the primitive rocks are buried thousands of feet below later sedimentary formations, such formations being intact over the whole area.

In 1837 Prof. Louis Agassiz propounded that theory known as the glacier theory in a paper read before the Helvetic Society of Natural History in his native country, Switzerland. It is thus concisely stated by Mr. Charles McLaren: "It was deduced from a careful study of the phenomena attending glaciers. . . . The Swiss philosopher advanced step by step. He satisfied himself that in the Alpine valleys, where glaciers still exist, they once rose to a higher level, and extended farther down into the low country than they now do. Next he discovered indications of their former existence on Mont Jura and over the whole Swiss valley; and, connecting these with similar indications found in the Vosges, the Scandinavian mountains, and elsewhere, and with the well-known fact of sheets of ice covering the northern shores of Siberia, and entombing the remains of extinct species of animals, he came to the conclusion that, at a period, geologically speaking, very recent, all the Old World north of the 35th or 36th parallel had been enveloped in a crust of ice. Whence the cold came which produced this effect, and why it afterward disappeared, are questions he did not feel himself bound to answer." This theory had been suggested before by Venetz, but had been applied by him only to the region of the Alps. Prof. Agassiz afterward more fully worked out his theory, giving facts, and careful measurements, and calculations, in his famous work entitled "Études sur les Glaciers."

Prof. Agassiz supposes that the eastern Alps were upheaved when the coating of ice was on the surface, this being the last cataclysm that has visited Europe. By this upheaval of the Alps the ice was disturbed, like the rocky formations. This was accompanied or followed by a higher temperature, and the thawing of the ice, which produced torrents and consequent valleys of erosion. The floods which followed the upheaval of the Alps were sufficient to float icebergs containing blocks of rock that might be deposited in different places, the water being at least 300 feet deep, and the agent that carried and deposited the fine drift in the valleys below. The catastrophe which enveloped the northern regions in ice was sudden, according to Prof. Agassiz, but the retreat of the glacier was slow.

This theory, so novel, so startling, met with various acceptance. By some it was loudly scouted as the product of the imagination solely; and was classed by Prof. B. Studer, a *savant* of the Continent of Europe, with the poetical Indian legends, wherein the periods of heat and life are made to alternate with periods of freezing and death. But its force lay in the inherent evidence of candor, and honesty in the statement of facts about which there could be no dispute. By the most enlightened geologists, both of the Old World and the New, it was received as a flood of light cast on what had before been dark and unexplained; and it was accepted with some caution and exceptions by such men as Prof. Buckland, Sir Charles Lyell, and Prof. Edward Hitchcock. At the present day but few geologists can be found in this country who do not admit the reality of the glacial epoch.

But, while it is true that but few geologists can be found in this country who do not admit the truth of the glacier theory of Prof. Agassiz, it is also true that a great many, perhaps the majority, also adhere to the iceberg theory of Peter Dobson. The two theories at first came in violent conflict. They diverged at the outset. One required the continent below the ocean, and the transportation of bowlders and other drift by floating ice; the other required it elevated high above the ocean, and the transportation of the drift by ice in the form of continental glaciers. How, then, can the same person hold to both theories?

Soon after the promulgation of the glacier theory by Prof. Louis Agassiz, Mr. Charles McLaren attempted to make it harmonize with the iceberg theory. He was seconded in the effort by Prof. Edward Hitchcock, who invented the term *aqueo-glacial*, to express the force, or forces, that operated to disperse the materials of the drift. In explaining the meaning of that term, he says, however, he cannot admit the glacier theory of Prof. Agassiz, and apply it unqualifiedly to this country; but, while acknowledging himself greatly indebted to Agassiz, he thinks that icebergs were the principal agents in transporting the drift. In the years 1841 and 1842 Sir Charles Lyell visited this country. His observations on the drift, published in various scientific journals, and repeated in his book of "Travels in North America," in 1845, furnish the basis for the most plausible union of these two theories. He divides the drift epoch into four parts:

1. The period of emergence of the land, during which some of the bold, rocky escarpments of the continent were formed.

2. A gradual subsidence and moderate submergence of the interior portions of the continent, during which icebergs floated over the surface of the ocean, grinding and marking the rocks.

3. The deposition of the clay, gravel, and sand, of the drift, with occasional fragments of rock, the last through floating ice.

4. Period of reëlevation and formation of lake-terraces.

Although not professedly aiming to reconcile the iceberg theory with the glacier theory of M. Agassiz, Mr. Lyell's eminent authority would not permit the total extinguishment of the iceberg theory, and his generalizations have, perhaps, had more influence in directing the efforts of others in such reconciliation than the writings of any other man. It required but very slight changes in Mr. Lyell's method of dividing the history of the drift to evolve, in its present aspect, the latest theory of geologists touching the origin of the drift-deposits. Mr. Murchison, of England, coincides with Mr. Lyell in the submergence, or iceberg theory. Mr. J. D. Dana advocates the glacier theory in its fullest extent; but, although adopting also the term *Champlain*, he is far from admitting the recent enlargement of that epoch, so as to bring the continent beneath the water of the ocean as required by the supporters of the combination theory.

Professors E. W. Hilgard, of Mississippi, and J. S. Newberry, of Ohio, are among the most prominent advocates in this country of this new theory, resulting from the combination of the glacier and the iceberg theories. Dr. A. Winchell, of New York, also advocates the same. It is as follows:

First. The glacier epoch proper.

During this epoch the continent was considerably elevated above its present level, especially in the north. This either produced, or was accompanied by, a greater degree of cold, the effect of which was to bring over the continent the vast sheets of ice in the form of continental glaciers, required by the hypothesis of Prof. Agassiz. During this epoch the rocks were scored, and many deep valleys were excavated. Large bowlders were transported to regions farther south.

Second. The submergence of the continent, attended by an amelioration of the climate and the disappearance of the glaciers, or their retreat to the far north. The assortment and stratification of the drift, produced by the glaciers, and the deposition of the great mass known as *Erie clay*, and other clayey portions of the drift-sheet. This condition of the continent was attended by the appearance of numerous icebergs which floated over the submerged land, and aided to transport the coarse drift, according to the hypothesis of Peter Dobson.

Third. The emergence of the continent with a halting progress, producing terraces and ridges marking the ancient levels of the ocean.

These three steps have been named by Prof. Dana, in their order, the *Glacial Epoch*, the *Champlain Epoch*, and the *Terrace Epoch*.

The studies of Professors Agassiz and Tyndall on the glaciers of the Alps, and of Dr. Kane on those of Greenland, have so fully demonstrated the adequacy of glaciers to produce all the effects attributed to them by the theory of Agassiz, that it is now very generally admitted that, wherever those phenomena are seen, glaciers must have existed.

Geology, having demonstrated thus the necessity for a period of cold, to account for the phenomena of the surface of the earth, labored under the difficult task of accounting for such change of climate on philosophical principles. It is here that the community of the sciences is beautifully illustrated. Astronomy comes to the aid of her younger sister, and Geology receives from her the solution she could not herself compass.

Astronomy makes known three great irregularities in the motions of the earth, requiring thousands of years each for their recurrence. They are—

1. The "precession of the equinoxes," combined with the revolution of the line of the apsides, produces a progression in longitude, of the aphelion place of the earth, bringing about a coincidence of the winter-solstice with the aphelion once in 21,356 years. At the present time our aphelion position occurs in the summer season.

2. Variation of the inclination of the earth's axis to the plane of its orbit. This passes through a double oscillation in about ten thousand years. Its effect is to carry the solstitial point through a small variation in latitude, and to that extent prolonging or withdrawing the influence of the sun's rays in the polar regions.

3. Change in the eccentricity of the earth's orbit. This irregularity passes from maximum to maximum once in about one hundred thousand years. Its effect is to lengthen those seasons nearest the earth's aphelion, and to shorten those nearest its perihelion. At the present time, our aphelion, occurring in the summer season, lengthens the warm months to that amount that, combined with the shortening effect of perihelion in winter, makes a difference of about eight days between the summer and winter months of the year.

The conditions favorable for polar glaciation are as follows:

1. Winter-solstice in aphelion.
2. Obliquity of the ecliptic at minimum.
3. Eccentricity of orbit in maximum.

The coincidence of these three causes would produce the greatest glaciation. The least multiple of their periods of recurrence is about forty-two million years. The second cause may combine a great many times with either of the others within that interval. Its effect being quite inferior to that of either of the other two, it may be disregarded, and the time required for the combination of the other two would then be 4,200,000 years, which would necessarily be preceded and followed by a number of approximations. These would occasion corresponding periods of increase and diminution in the degree of cold that would not reach the maximum cold incident to their coincidence. Probably the most powerful of the causes enumerated is the occurrence of the winter-solstice in aphelion, which alone may have produced the last glacial epoch. In that case changes in the prevalence of the ice would be due to the operation of cause No. 2, or the obliquity of the ecliptic. The earth is now 622 years past its period of south-polar glaciation in the operation of cause No. 1, and is entering upon its period of north-polar glaciation. Its last glacial epoch in the operation of this cause occurred in the Northern Hemisphere in its acme of intensity at a period 11,300 years ago.

The effect of these irregularities in the motions of the earth on the climate has been ably discussed by Mr. James Croll, of the Geological Survey of Scotland ("Transactions of the Geological Society of Glasgow," vol. ii., part iii., p. 177), and detailed calculations on the periodicity of these variations have been made by Mr. Stockwell, of Cleveland, Ohio.

Let us endeavor to picture the recurrence of one of these coincidences, and to rehearse some of the phenomena of an actual period of continental ice.

The precipitation of the winter season is all preserved on the ground in the form of snow and ice. It constitutes what has been denominated *névé*. The advent of the summer season is not powerful enough to melt the accumulations of the long winter. The *névé* is simply converted into granulated ice. Another winter adds to the thickness left by the preceding. Another summer changes it to ice. Some water may be the result, but it is congealed in the streams, or perhaps escapes to the ocean. This succession is continued, with a slow increment of cold, through thousands of years. The ice-mantle becomes continental in its extent. Its thickness reaches hundreds of feet. Toward the pole this may be increased to thousands or tens of thousands. It has a great weight. It presses upon itself. Its lower portions yield to the inequalities of the rocky surface. The mass seeks the valleys. It slides down the mountain-sides, carrying the *débris* which it detaches in its descent. It covers the broad plains. The accumulations toward the north, ever increasing, press out toward the south, the foot of the ice-sheet. A general movement is developed by reason of the gravity of the mass, the fracturing and regelation of its parts, and the molecular forces that allow it to yield under pressure. Each recurring summer develops more or less water. This water perhaps enters the openings and crevasses, and washes out some of the obstructions, facilitating the general progress. The main water-sheds separating valleys serve also as ice-sheds. The valleys are more rapidly dug out by the rasping and ploughing movement of the glacier than are the highlands. In the valleys the ice flows most rapidly. In the valleys, also, the ice is prolonged much farther into warmer latitudes than on the highlands. Southward, prolongations of the ice-sheet follow the north-south outcropping edges of argillaceous formations. Lake Michigan lies in one of these troughs. Lake Huron lies in another. Lakes Erie and Ontario are only shallow basins dug out of soft rocks by ice that passed southwestwardly. The shale-bed that gave rise to Lake Ontario also determined the location of Georgian Bay and of Green Bay. The basin of Lake Erie is much shallower toward the west end than toward the east, and it finally runs out altogether by reason of the westward attenuation, and finally the entire disappearance of the *salina* formation in which it is largely excavated. The ice was then thrust up on to harder rocks that form the basis of Northwestern Ohio and Northeastern Indiana. Lake Michigan was terminated southwardly by the eastward trend of the rocky outcrops at an angle that the ice could not follow. The Red-River flats of Minnesota correspond to the Winnipeg basin in the same way that the Black-Swamp district of Ohio does to the Lake-Erie basin, or the prairie district surrounding the southern end of Lake Michigan does to the basin of that lake.

It must be remembered, however, that throughout the continuance of the ice-period the motion of the ice brought it finally into a climate where it could not exist as ice. It gave rise to countless streams of water. The broad, level country of the Northwest was not sufficiently irregular to gather the ice, and consequently not the water, into valleys having a north-south direction. The water from the ice acted all along the ice-foot with a comparatively uniform energy. If it was ultimately gathered into large streams, it must have been at considerable distances from the glacial field. It must be remembered also that the accumulated precipitation of the entire year over broad, continental areas was preserved from thaw till it arrived at the latitude of the limitation of the glacier, and there its full volume was discharged. It was as if the entire precipitation of the continent—say from the latitude of Chicago to the north-pole—were concentrated on a belt of territory, say of fifty miles in width, running east and west across the continent, and having the direction of the marginal line of the ice-foot. Thus a constant sheet of turbid, running water would act on all objects over which the ice-foot retreated.

We must not forget, in recalling to our imagination the scenes and events of the ice-period, to inquire what were the position and the condition of the drift to which it gave origin.

In regions far to the north, the eye probably would not be able to discern any object except that of the universal ice. The surface of the ground would be thousands of feet below the traveller, if we may be permitted to presume so hardy a human being. Like Dr. Kane exploring the great Humboldt Glacier of Greenland, he would meet with countless obstacles and dangers. But those obstacles would consist of hummocky ice, or crevassed ice, or perpendicular ice-walls. He would see no soil, no rocks, no vegetation, no animal life. The winds would whistle, storms would rage, snow would be drifted about, and the ineffectual sun would rarely venture to smile on the dreary waste. Farther to the south, the explorer would find isolated spots of bare ground. He would see about them the accumulated *débris* of bowlders, gravel, and dust, from constant winds, spread more or less over the ice-field, staining its painful whiteness, and showing the more grateful aspect of earth and stones. Another hundred miles farther south, and he finds the evidences of the dissolution of the ice-sheet multiplying. Occasional streams of water run on the surface of the ice, or plunge into some of its openings. Deep gorges reveal multitudes of fragments of rock frozen into the ice, and occasional bands of dirt and gravel embraced in the solid ice. The surface is everywhere dirty, or perhaps muddy, from the wasting away of the surface of the glacier. He meets frequent openings, in which generally water may be seen or heard. Into these gorges the *débris* slides down the sloping sides, increasing the insecurity of his footsteps. Still farther south, the general surface is covered with a pulpy earth, mingled with stones and bowlders. The ice is evidently much attenuated. The areas of firm, uncovered *terra firma* are wonderfully increased in size and frequency. The ice itself is crowded into the valleys, or, if it be in a broad, level tract, like the State of Minnesota, the surface is covered with the *débris* of the conflict of ice with earth, the ice itself being visible only in those places where crevasses reveal it, or where deep gorges are worn by running streams. Travelling still farther south, the explorer would come upon large areas in which he would not be able to know whether the glacier underlay the superficial drift or not. If he were to stop on one of those wide areas, and make his latitude and longitude certain, by a series of astronomical observations, he might find to his surprise, after a few years' residence, that his observatory and apparatus had been bodily carried, by an imperceptible motion, some rods to the south. If he were to penetrate the earth on which his foothold seems so steadfast, he might find, equally to his surprise, that he was still riding on the surface of a vast ice-sheet, the earth and soil of which may have furnished him annual crops of potatoes and barley. In other places in the same latitude he would find the ice laid bare over considerable areas, washed clean by the drainage incident to the dissolution of the glacier. The turbid streams would be vastly larger than those which occupy the same beds to-day. They would run with tenfold more violence. The drift-materials would be freed from the clayey portions, and be spread along their channels in curious and varying assortment. In some places the thickness of the whole sheet of drift would be brought under this washing and stratifying process. In others, the ice gently dies out, and lets it down on the rocky surface without any change from the condition in which it lay on the glacier.

If, at last, the explorer travels far enough south to actually leave the area of the glacier, what is the condition of the surface? *It is plainly one of glacier-drift.* In some places he will find the various parts, such as gravel-stones, sand, clay, and bowlders, confusedly mingled, showing no assortment or stratification. The clay which has resulted from the grinding action of the glacier on the surface on which it lay, from dust blown over the ice by violent winds, as in the Alps, and from the sediment washed on the ice from the higher knobs that first became uncovered, fills all the interstices so closely as to make of the mass an impervious and uniform hard-pan. This has generally been denominated " unmodified drift." It is that which escaped the assorting action of the water issuing from the glacier. In other places, this unmodified drift would be superficially assorted, showing the effect of running water after its deposition or in the act of deposition. Probably very much of that portion of the drift that lay in the course of the broad Mississippi, yet south of the limit of the glacier, would be superficially worked over, losing much of its clay. We actually see vast tracts on the Upper Mississippi, and even in the latitude of St. Paul, in which the surface consists, to a considerable depth, principally of stratified sand and gravel. He would also find parallel ridges of drift-materials, consisting largely of the coarser portions, and showing stratification where water passed over or through it in being deposited. Some such ridges would still retain the most or all of the original clayey portions. This would be the case where the drainage was not powerful. Such ridges mark the places at which the retreat of the ice was temporarily stopped by a period of greater cold, the slow advancing of the ice under the propulsive forces already named serving to heap up a greater amount of detritus all along the ice-margin. These ridges are known as *moraines*, and they occur in all parts of the drift-latitudes. They are developed on a very grand scale in Northwestern Ohio.

There is still one important point in this discussion that must not be omitted. It is plain to see that, in some parts of the Northwest, the advance of the continental glacier would be up gentle slopes, instead of descending an incline. These slopes, of course, present obstructions to the movement of the ice in those directions. It is true, also, that the continental glacier would tend to level the country and obliterate such northward slopes. But, in the later part of the ice period, the valleys would be the last relinquished, and would be deeper dug by isolated branches or spurs from the main ice-sheet, which would conform in their direction to the contour of the valleys they might occupy. All glaciers, however, whether continental or local, would avoid an ascent if there were any other passage. Now, when a glacier, propelled by a force exerted far to the north, meets with a gentle slope toward the north, the water which issues from its foot will be confined in a lake about the foot of the ice, and will rise to the height of the lowest outlet. Into this lake may flow streams of considerable size, bringing their sediment from the south, east, or west, according to the topography. Here we should have, then, a constant accession of drift from two sources, the chief of which would be, of course, the glacier itself. As this drift is brought under the influence of standing water, its fine parts are floated away by currents and waves, to be spread over the bottom of the lake in horizontal laminations, the principal portion, and notably the bowlders, sinking at once to the bottom unassorted. Thus, by the continued slow withdrawal of the field of ice, the result is a layer of unassorted drift overlaid by a thickness of handsomely-laminated fine clay and sand. This combination of circumstances must have occurred south of Lakes Erie and Huron, producing the Black Swamp and the Cottonwood Swamp in Ohio and Michigan, about the south end of Lake Michigan, and over an extensive flat south of the Winnipeg basin.

All the phenomena of the drift in the Northwest are, hence, attributable to the approach, long duration, and slow disappearance of the glacier-ice of Prof. L. Agassiz. It certainly seems unwarrantable to propose upward and downward movements of the crust, involving the submergence of the continent, when one simpler cause can be shown sufficient to produce the known effects. The submergence of the New-England coast to the depth of about seventy feet is all that Prof. J. D. Dana finds warranted by a vigorous inspection of the drift-deposits about New Haven, Connecticut. The four-hundred-foot "beach," near Montreal, may have the same origin as the so-called "beaches" that rise several hundred feet higher in the State of Ohio. The Champlain and Terrace Epochs find no application to the drift in the Northwest, as those terms are defined and used in the East. There is abundant evidence throughout the West of a former higher stage of the rivers. This higher stage may, however, be explained by referring it to the large increase of water incident to the melting of the glacier only after reaching the latitude of a warmer climate. The terraces have not, moreover, in the Northwest, generally that system or uniformity of height and arrangement necessary to warrant their reference to successive reductions in the volume of water, but are usually due to a variable resistance offered by the banks or rocks in which they occur, arising from their stratification.

No well-authenticated fossil remains from the hard-pan drift have yet been met with. Statements have been published of the finding of fossil remains in the unmodified drift in various parts of the Northwest, but they are generally based on the reports of non-scientific observers, and must be taken with great caution, unless verified by a geologist who has definite ideas of what "modified" or "unmodified" drift is. It would not be improbable that, near the southern margin of the ice-field, the remains of vegetation, and even of animals, should be involved in the drift undergoing transportation, but their structures are too fragile to withstand the grinding incident to the general progress of the ice, and would not bear transportation from northern latitudes. Much uncertainty is also thrown on the true age of vegetable remains, reported from the drift in the Northwest, by the wide-spread but hardly distinguishable clays of the Tertiary and Cretaceous formations, which contain modern species of wood and leaves, associated with marine fossils.

Believing, therefore, in the *glacier* origin, directly, of the Post-Tertiary deposits of the Northwest, it is impossible to concur in the supposition recently expressed by an eminent authority relative to the probable blending of those deposits with the marine deposits of the Tertiary: "A careful study of these modern deposits" (meaning the Quaternary) "will undoubtedly show consecutive links by which it was united to the Tertiary period, in the same manner as the Cretaceous and Tertiary are connected." [1] It is difficult to conceive how the sedimentary deposits of an epoch of submergence, like the Tertiary, which abound in marine fossils, can show, however carefully studied, consecutive links of connection with an epoch of *débris* transported and deposited through the agency of vast continental glaciers.

St. Anthony, Minnesota, *March*, 1873.

DOMESTIC ECONOMY OF FUEL.

By Captain DOUGLAS GALTON, C.B., F.R.S.

II.

THE question of saving fuel for cooking purposes is even more important than economy in warming; because cooking is an operation required every day in the year, and the waste of fuel in cooking is even more considerable than in warming.

An ordinary cooking-range in houses, which, for convenience, may be designated middle-class houses, is derived from the time when the same fire was used for cooking and for warming. It is interesting to consider Count Rumford's remarks on this question. He largely developed the use of steam for cooking in large establishments, but, in considering private kitchens, he showed that nine-tenths of the heat produced in cooking operations were wasted, and only one-tenth utilized in cooking, by the use of open fireplaces. He laid down the following principles on fireplace construction:

1. Each fireplace should have its grate on which the fuel must be placed, and its separate ash-pit, which must be closed by a door well fitted in its frame and furnished with a register for regulating the quantity of air admitted into the fireplace through the grate. It should also have its separate canal for carrying off the smoke into the chimney, which canal should be furnished with a damper or register. By means of this damper and of the ash-pit door, the rapidity of combustion and generation of heat is regulated, and on the proper use of the two registers the economy of fuel will much depend.

3. In fireplaces for all boilers which are too heavy to be easily lifted with the hand, an opening just above the level of the grate should be made for introducing fuel to the fire, which opening must

[1] Prof. F. V. Hayden, in "Geology of Wyoming."

be closed by a close-fitting stopper or door. In fireplaces constructed for small stew-pans this opening may be omitted, and the fuel be introduced through the opening into which the stew-pan is fitted, by removing the stew-pan occasionally for the purpose.

4. All portable stew-pans should be circular, and suspended in their fireplace from the circular rim. The best form for large fixed boilers is an oblong square, broad and shallow rather than narrow, and deep, and it should be of thin metal.

5. All boilers and stew-pans should be fitted with covers to render them well adapted for confining the heat. The best arrangement is to make the covers of thin sheets of tinned iron, and double, that is, with an air space between the outer and inner cover.

We have, during the last twenty years, introduced, as a rule, close ranges. They are certainly cleaner and more convenient for cooking, and, if great care is exercised in the use of the dampers, they will be found more economical than open fires. But, as a rule, they are based on the principle of making one fire perform a variety of operations. Independently of the question of a combined fire, as compared with the separate fires advocated by Count Rumford, a consideration of the form of modern kitchen-ranges will show that most of the principles laid down by him have been entirely neglected. The doors of the fireplace and ash-pit seldom fit close; the boilers are rather deep and narrow than broad and shallow; the use of the hot-plate prevents the stew-pans from being suspended from the rims for the fire to play round them; the use of double covers for saucepans and boilers is rather a rarity than a usual arrangement.

To realize the question of economy of fuel, it is necessary to consider, in the first place, what a given quantity of fuel is capable of doing. As regards hot water, if water is kept at a temperature of 200°, or from that to 210°, the gases from the fire can, after communicating the heat to the boiler, pass off into the chimney at a temperature of little beyond that point; but, if the water be allowed to boil, in the first place a large amount of latent heat is absorbed by the steam, which is lost if the steam passes off into the air or the chimney, and, in the second place, it will be found that the gases, after they pass off from the boiler, will have a temperature of as much as 300°, 400°, and even 500°. Unless, therefore, water is required to be actually boiling for use, if the water is permitted to boil, a great quantity of heat is wasted up the chimney. For household purposes it is never necessary that the water in the boiler should exceed 200°. Tea, to be good, should be made (as clearly shown by Mr. Francis Galton in his "Art of Travel") with water of a temperature of from 180° to 200°. Very few culinary operations require the water really to boil, and, when boiling water is wanted, it is required in a saucepan standing on the fire. All operations of cleaning, etc. (except washing clothes), require water at a very much lower temperature than 212°. If, however, water at a higher temperature is wanted, it can be supplied up to about 230° without the generation of steam, by heating it under pressure; this can be attained by having a close boiler fed from a cistern placed at the top of the house. For the preparation of preserves and some other cooking operations, such a system is most convenient.

One pound of coal should raise from fifty to sixty gallons of water from 45° to 212°, and, when raised, very little fuel is required to maintain it, in a properly-constructed boiler, at that temperature. The total amount of water, at such a temperature, used daily, in an ordinary middle-class house, does not exceed thirty or forty gallons, and, therefore, if the boiler were made so as to absorb as much heat as possible, the hot water used in an ordinary middle-class house, with a family of ten or twelve persons, ought not, with thorough economy, to consume more than one-sixth of a ton of coals in the year. Count Rumford shows in his treatise that 25 lbs. of bread ought to be baked with one pound of coal, and that 100 lbs. of meat should be cooked with 2¼ lbs. of coal. If, therefore, we fully utilized our fuel, it is clear that, in the preparation of our food and hot water for domestic purposes, ½ lb. of coal per head of the population ought to be a sufficient daily allowance, which would be equivalent to one-twelfth of a ton per annum, and in large households even less than that quantity ought to suffice. I do not suppose that we should ever attain to this minimum of consumption, but it is well to consider what the standard is, so that we may not rest satisfied till it has been much more nearly approached than hitherto.

Economy has, as I before observed, latterly been sought in combined apparatus. Where large numbers of persons have to be cooked for, and where, consequently, a carefully-constructed apparatus is always worked to its full extent, the results which have been obtained show a very moderate consumption of fuel; but the same apparatus, when used for smaller numbers of persons, gives results not favorable to economy.

The boilers in use in barracks, when I first took up the question, required from 16 ozs. to 20 ozs. of coal per head to supply water for breakfast and tea, and washing up, and to make soup for dinner for fifty or sixty men. The boilers I introduced would perform the same duty with from 3 to 4 ozs. of coal for each person cooked for, provided the number amounted to fifty or sixty persons. The ovens for roasting, which I introduced into barracks, would roast and bake with 1 oz. of coal for each person cooked for, when cooking for the full number for which the oven was designed, and for such numbers as 200 to 400 persons; smaller ovens would require 2 ozs. per head when cooking for 50 men. Of course, to produce these effects, great care was required.

Messrs. Benham introduced cooking apparatus which, when cooking for the full number of 300 soldiers, would perform the total daily cooking and supply of hot water in barracks, with from two to three ounces of coal per person cooked for.

Captain Warren constructed an apparatus to boil, bake, steam, roast, and fry, and provide hot water, which, when cooking for about 100 men, required somewhere about 2¾ ozs. for each person cooked for, but, when cooking for forty men, required 6 oz. per head, and when cooking for sixteen men the average of several days amounted to 9 ozs. or 10 ozs. per man cooked for, but on one or two of these days the consumption did not exceed 5 ozs. for each person cooked for.

These apparatus supplied to the men all the cooking and hot water necessary. The results show what degree of economy has been reached in ordinary practice with soldiers, who are not proverbial for care, and what, therefore, should be the standard of economy to which we have a right to expect to attain. No doubt, private houses containing sixteen persons might require more hot water or more cooking, but according to these facts, as to ascertained consumption of fuel, the expenditure of fuel in the kitchen for a family consisting of sixteen persons might easily be reduced to 1½ or 2 tons per year, and in all these apparatus further elements of economy remain to be developed.

The conclusions, however, to which I have been led in my consideration of this question, are, that with these apparatus, and, indeed, with all kitchen-ranges in use, the waste of heat lies in the number of functions the fire has to perform. It must warm water, it must heat the oven, it must stew, and grill, or toast, and sometimes roast at the open fire, and each of these processes requires a different condition of heat. Hot water requires a temperature of 200° to 210°, a roasting-oven of about 450°, a baking-oven probably 350°; grilling is performed on a clear flame, the temperature of which is probably 1,300°. Now, when the fire is in an efficient condition to perform one of these functions, it is also in an efficient condition to perform the others, and, although, by means of dampers, it may be somewhat checked in the performance of its full functions in certain directions, there is no doubt that an enormous amount of heat is wasted through the agency of those parts which are not wanted to be in operation. When the oven is not wanted, it is affording a means for the heat to escape rapidly, especially if ventilated as a roasting-oven. The boiler is supplied with heat beyond its requirements, and generally abstracts a large quantity of spare heat, which passes off in the shape of steam. I assume that the cook closes the dampers in order, as far as possible, to limit the action of the fire when cooking is not going on, but in practice this is difficult to insure. With these combined apparatus, the fuel consumed will be in proportion to the various operations which the fire is arranged to perform, and not in proportion to the limited work required when only one or other of the operations is wanted. When, for instance, the fire is only wanted to heat water, a great waste of heat will be going on, from the heat passing off from the oven, hot-plate, and front of the fire. For this reason, the combined apparatus can never be so economical in fuel as separate apparatus; while, however, apparatus of this class, if not very carefully worked, waste fuel, they, to some extent, save trouble to the cook.

I have already mentioned several points of detail where fuel could be saved in our kitchen-ranges, viz., by great attention to the close fitting of the ash-pit and fire-grate doors, the use of double covers to saucepans and boilers, the use of sand on the hot-plate to prevent the escape of so much heat from that part; and, beyond these, an important point in securing economy is the separation of those culinary processes which require different gradations of heat. The three main parts of the ordinary cooking apparatus are the oven for baking and roasting, and the boiler, and the hot-plate. If the boiler is to be of the form most effectual in saving fuel, the flame and gases from the fire should play under and round every part of it; the water should be kept at something under 212°, so that the gases, after leaving the boiler, may not enter the flue much above that temperature, and, inasmuch as that is a higher temperature than is necessary for the purpose of producing a sufficient draught in an ordinary chimney, the heat in these gases should be still further utilized. In the first place, they should be used to warm the water which will be required to replace what is drawn off from the boiler; and, in the second place, an economy can be obtained by employing the gases, which pass off into the chimney at a temperature above what is required for creating an efficient draught, to warm the air supplied to the fire for purposes of combustion. The experiments which I have made on the supply of warmed air to feed the fire have, unfortunately, not been worked out sufficiently to enable me to give them in a clear form with exact results; but an economy of from six to nine per cent. might be obtained from this source.

Then, as regards the oven. The baker's oven, of fire-brick, in which the fire is made inside the oven, and the whole heat retained in and reflected back from the sides and top and bottom, is a very economical instrument when in continual use. With iron ovens, attached to a kitchen range, the case is different. An oven which roasts requires a temperature of from 400° to 450° at least. Therefore, to maintain this temperature, the gases must pass off into the flue at a temperature even higher; when the oven is a roaster, a considerable volume of air is being continually passed through it to carry off the steam from the meat. This air, if admitted cold, as is the case with many ranges, acts so as to cool down the interior, and therefore additional fuel has to be consumed to counteract this cooling-down process. Now, however good may be the conducting power of the material used for ovens or boilers, a coating of soot diminishes the conducting power very rapidly, and consequently the temperature of the flue conveying heat to the oven will always exceed that of the inside of the oven. It is, therefore, of great importance to remove any causes which tend to lower the inside temperature. Hence it is desirable to utilize some of the heat which passes off, at above 450°, into the flue, for the purpose of raising the temperature of the air to be admitted into the oven. As a general rule, however, and except in some apparatus, under present arrangements all this heat is wasted, and it certainly cannot be utilized properly so long as one fire is retained to perform so many separate operations.

The hot-plate is the third important part of the modern close cooking-range. Count Rumford proposed that the top of a hot-plate should be covered with sand, and the sand cleared away only under the saucepans. In its present shape, the hot-plate wastes an enormous amount of heat. It is wasteful, because it radiates the heat largely; because the application of heat to the saucepans is only through the bottom of the saucepan, and the bottom of the saucepan is not always in immediate contact with the flame, but is frequently allowed to receive the heat through the medium of the cast-iron hot-plate, which is a very moderate conductor of heat. Just consider what the difference of effect is. The heat of the flame, if directly acting on the bottom of the saucepan, would be 1,200° Fahr., but, unless the hot-plate is red-hot, probably not above 450° will pass through, but the heat in the flue which heats the hot-plate will be at 1,200°, and the spare heat from the flame will be wasted up the chimney. The hot-plate should be dispensed with, if economy is to be made paramount, and charcoal burners substituted for it. Where gas is available, the hot-plate can be dispensed with without extra trouble to the cook. The gas-burners should be properly protected in sunken holes, with side of fire-clay, and the saucepans should be dropped into the holes, so that the full effect of the heat shall be concentrated on them and round their sides, and the gas should be only kept lighted so long as the operation to be performed is going on. It may be assumed that one pound of coal is equivalent to from 28 to 30 cubic feet of gas; hence, as permanent fuel, gas would not be economical; but the simplicity of its application makes it a very convenient fuel in cooking, and economy is obtained from its use, because the full effect of the combustion can be utilized as soon as the gas is lighted, the flame can be regulated to any required extent, and the gas be extinguished as soon as the required operation is performed.

I have endeavored to enumerate, briefly, the economical conditions which should regulate the consumption of fuel for domestic purposes. By economy it is meant that, while all necessary operations of warming and cooking continue to be performed, the fuel employed should be utilized to the utmost. In the kitchen, the daily consumption of fuel, in small establishments, should not exceed half a pound of coal for each person cooked for, and in large establishments the proportion should be smaller. In the consumption of fuel for warming, so many conditions have to be considered that no standard can be laid down beyond the broad fact already stated—that one-sixth of the coal we commonly now use would suffice for all our requirements if it were properly utilized. I do not, however, anticipate that much progress will be made in economy, unless the price of coals should remain at a figure which will induce the householder to make himself thoroughly acquainted with the principles on which the apparatus for warming and cooking should be constructed and worked; for there is no apparatus which can be invented which will not depend, to a considerable extent, on the manner in which it is attended to.

The principal conditions which I have enumerated have long been known. There is an old saying in South Staffordshire, that "he who lives longest must carry coal farthest," and, acting on this, we have, year after year, simply wasted millions of tons of coal in our domestic fireplaces, because the coal was provided at a small cost, and we have had no thought for posterity.

George Stephenson once said, very happily, that coal represented the accumulated rays of the sun laid up in store in by-gone days. When this store is gone, the world will have lost the most convenient and economical means of generating heat. It is, therefore, a duty, which every man owes to posterity, to do his utmost to husband this great store.

I have endeavored to do my part by explaining the conditions which should govern the arrangements devised for regulating the consumption of fuel for domestic purposes. It remains for the public to insist on having these principles applied to the various apparatus which they adopt.—*Journal of the Society of Arts.*

ON THE HEREDITARY TRANSMISSION OF ACQUIRED PSYCHICAL HABITS.

By Dr. WILLIAM B. CARPENTER, LL. D., F. R. S.

PROCEEDING, now, to show that the tendency of modern Physiology is to prove the existence of a distinct *causal* relation between Physical changes in the Nervous System and definite modes of Mental action, it may be well for me to adduce, *in limine*, the positive evidence that *all* Mental activity is dependent on a Chemical reaction between the Blood and the Brain: for, although this is one of the best-established facts in Physiology, it is, I believe, taken very little account of by Metaphysicians.—The Brain is supplied with Blood by four Arterial trunks, which enter the cranial cavity at no great distance from one another, and then unite into the "Circle of Willis;"

from which are given off the various branches that distribute arterial blood to every part of the brain-substance. After traversing this, the blood returns by the Veins, greatly altered in its chemical composition; especially as regards the loss of free oxygen, and its replacement by various oxy-compounds of carbon, hydrogen, phosphorus, etc., that have been formed by a process analogous to combustion. Now, if one, two, or three of the Arterial trunks be tied, the total supply of blood to the Brain is diminished; but, in virtue of the "Circle of Willis," no part is entirely deprived of blood; and the functional activity of the Brain is still maintained. If, however, the *fourth* artery is compressed so as to prevent the passage of blood, there is an *immediate* and *complete* suspension of activity; the animal becoming as unconscious as if it had been stunned by a severe blow, but recovering as soon as the blood is again allowed to flow through the artery. In fact, the "stunned" state produced by a blow on the head is *not directly* dependent upon the effect of that blow on the Brain, which may have sustained no *perceptible* injury whatever; the state of insensibility being due to the paralysis of the Heart and suspension of the Circulation, induced by the "shock:" and the like paralysis with the same result may be produced by a blow on the Epigastrium (acting on the great "solar plexus" of nerves), or some overpowering Mental emotion.—Again, there is a curious affection termed Hysteric Coma, which consists in the sudden supervention of complete insensibility, and the equally sudden and complete return of conscious intelligence, without any other indication of Brain-disorder. The insensibility may come on while the patient is talking, so as to interrupt the utterance of a sentence; and, the moment that it passes off, the series of words is taken up and completed, without the patient being aware that it has been interrupted. With our present improved knowledge of the action of the "vaso-motor" system of Nerves in producing local contractions of the Arteries, and of its liability to be influenced by those Emotional irregularities in which Hysteria essentially consists, we can scarcely doubt that this affection is due to a temporary disturbance of the Circulation through that agency.—Further, if the Blood transmitted to the Brain, though not deficient in quantity, be depraved in *quality* by the want of Oxygen and the accumulation of Carbonic acid (as happens in Asphyxia), there is a gradually increasing torpor of the Mental Faculties, ending in complete insensibility.

Thus the dependence of Mental activity of even the most elementary kind, upon the Physical changes kept up by the circulation of oxygenated Blood through the Brain, can be shown experientially to be just as direct and immediate as is the dependence of the Electric activity of a Galvanic battery upon the analogous changes taking place between its Metals and its exciting Liquid.—If we say that Electricity is the *product* of Chemical change in the one case, I see not how we can refuse to regard Thought as the *product* of Chemical change in the other; nor (in the view that all the Forces of Nature are simply expressions of Mind) do I see that we need entertain any repugnance to such a view. I do not say that it *explains* any Mental phenomenon. No sound Physicist would say that he can "explain" how it is that Electricity is generated by Chemical change; but he knows that such a relation of cause and effect exists between the two orders of phenomena, that every Chemical change is accompanied by an Electric disturbance; so that, whenever he witnesses Electric disturbance, he looks with assurance for some Chemical change as its Physical Cause. And in precisely the same sense, and in no other, I affirm that the Physiologist *must* regard some change in the Nervous substance of the Brain as the immediate Physical cause of all *automatic* Mental action. If this be admitted of Sensational consciousness (and how can it be denied?), we can scarcely help admitting it of Emotional; and, if of Emotional, why not of Ideational?

There is no part of our purely Physical activity, the relation of which to Physical conditions is more obvious and more intimate, than that *Reproduction of past states of Consciousness*, which—when supplemented by the *recognition* of them as having been formerly experienced—we call *Memory*. It is now very generally accepted by Physiologists as (to say the least) a *probable* doctrine, that *any* Idea which has once passed through the Mind, *may* be thus reproduced, at however long an interval, through the instrumentality of Suggestive action; the recurrence of any other state of Consciousness with which that Idea was originally linked by Association, being adequate to awaken *it* also from its dormant or latent condition, and to bring it within the "sphere of consciousness." And as our Ideas are thus linked in "trains" or "series," which further inosculate with each other like the branch-lines of a railway or the ramifications of an artery, so, it is considered, an Idea which has been "hidden in the obscure recesses of the mind" for years—perhaps for a lifetime—and which seems to have completely faded out of the *conscious* Memory (having never either recurred Automatically, or been found capable of recall by Volitional Recollection, or been recognized as a past experience when again brought before the mind), may be reproduced, as by the touching of a spring, through a nexus of Suggestions, which we can sometimes trace out continuously, but of which it does not seem necessary that all the intermediate steps should fall within our cognizance. Such a "reproduction" not unfrequently occurs when persons, revisiting certain scenes of their childhood, have found the renewal of the Sensorial impressions of *places* bring vividly back to their minds the remembrance of *events* which had occurred in connection with them; and which had not only been long forgotten by themselves, but, if narrated to them by others, would not have been recognized by them as having ever formed part of their own experience.

And it is not a little significant that the basis of such Memories appears capable of being laid at a very early period of life; as in the two following cases, of which the first is recorded by Dr. Abercrombie, while the second was mentioned to me by the subject of it:

"A lady, in the last stage of chronic disease, was carried from London to a lodging in the country. There her infant daughter was taken to visit her, and, after a short interview, carried back to town. The lady died a few days after, and the daughter grew up without any recollection of her mother, till she was of mature age. At this time she happened to be taken into the room in which her mother died, without knowing it to have been so. She started on entering it, and, when a friend who was with her asked the cause of her agitation, replied, 'I have a distinct impression of having been in this room before, and that a lady who lay in that corner, and seemed very ill, leaned over me and wept.'"—(*Inquiries concerning the Intellectual Powers*, fifth edition, p. 120.)

"Several years ago, the Rev. S. Hansard, now Rector of Bethnal Green, was doing clerical duty for a time at Hurstmonceaux, in Sussex; and, while there, he one day went over with a party of friends to Pevensey Castle, which he did not remember to have ever previously visited. As he approached the gate-way, he became conscious of a very vivid impression of having seen it before; and he 'seemed to himself to see,' not only the gate-way itself, but donkeys beneath the arch, and people on the top of it. His conviction that he must have visited the Castle on some former occasion, although he had neither the slightest remembrance of such a visit, nor any knowledge of having ever been in the neighborhood previously to his residence at Hurstmonceaux, made him inquire from his mother if she could throw any light on the matter. She at once informed him that being in that part of the country when he was about *eighteen months* old, she had gone over with a large party, and had taken him in the pannier of a donkey; that the elders of the party, having brought lunch with them, had eaten it on the roof of the gate-way, where they would have been seen from below, while he had been left on the ground with the attendants and donkeys.—This case is remarkable for the vividness of the Sensorial impression (it may be worth mentioning that Mr. Hansard has a decidedly artistic temperament), and for the reproduction of details which were not likely to have been brought up in conversation, even if the subject of them had happened to hear the visit mentioned as an event of his childhood; and of such mention he has no remembrance whatever."

Now, there is very strong reason to believe that what is described as a storing-up of Ideas in the Memory is the Psychological expression of Physical changes in the Cerebrum, by which Ideational states are permanently registered or recorded; so that the "traces" left by them, although remaining so long outside the "sphere of consciousness" as to have *seemed* non-existent, may be revived again in full vividness under certain special conditions—just as the invisible impression left upon the sensitive paper of the Photographer is "developed" into a picture by the application of particular chemical substances. It must be freely admitted that we have at present no certain knowledge of the precise mode in which this record is effected; but, looking at the manner in which the Sensori-motor apparatus, which is the instrument of our *bodily* activity, shapes itself to the mode in which it is habitually exercised, we seem justined in assuming that the same thing is true of the Cerebrum, which is the instrument of our *mental* activity. For in no other way does it seem possible to account for the fact of very frequent occurrence, and noticed in a previous paper, that the presence of a Fever-poison in the blood—perverting the normal activity of the Cerebrum so as to produce *Delirium*—brings within the "sphere of consciousness" the "traces" of experiences long since past, of which, in the ordinary condition, there was no remembrance whatever.

The same occurrence has been noticed as a consequence of accidental blows on the head; though these more commonly occasion the *loss* than the *recovery* of a language. The following case of this kind is mentioned by Dr. Abercrombie, as having occurred in St. Thomas's Hospital:

"A man who had been in a state of stupor consequent upon an injury of the head, on his partial recovery spoke a language which nobody in the hospital understood, but which was soon ascertained to be Welsh. It was then discovered that he had been thirty years absent from Wales, and that, before the accident, he had entirely forgotten his native language. On his perfect recovery, *he completely forgot his Welsh again*, and recovered the English language."—(*Op. cit.*, p. 148.)

It seems perfectly clear, then, that, under what we cannot but term purely *Material* conditions, strictly *Mental* phenomena present themselves. It is common to the whole series of cases, that the Automatic play of the "Mechanism of Thought" does that which Volition is unable to effect. Whether it be the *toxic* condition of the Blood, or the simple excitement of the Cerebral Circulation generally, or the special direction of Blood to a particular part of the Brain, it is beyond our present power to tell; but, as *all* Brain-change is (like the action of any other mechanism) the manifestation of Force, the production of these *unusual* Mental phenomena, by the instrumentality of an unusual reaction between the Blood and the Brain-substance, is no more difficult of comprehension than that of *ordinary* forms of Psychical activity, which we have seen reason to regard as the results of the translation (so to speak) of one form of Force into another.

The intimacy of the relation between the Psychical phenomena of Memory and Physical conditions of the Brain is further shown, by the effect of Fatigue and the impaired Nutrition of Old Age in *weakening* the Memory, and of disease and Injury of the Brain in *impairing* or *destroying* it. Every one is conscious of the difference in the activity of the reproductive faculty in which Memory consists, according as his mind is "fresh," or his head feels "tired." The latter state, in which the Automatic activity and the directing power of the Will are alike reduced, is clearly dependent, like the feeling of muscular fatigue, on the deterioration of the Organ, or of the Blood, or of both combined, which results from the prolonged exercise of it: and it is especially in our inability to *recollect* something which we *wish* to call to mind, that this failure of power shows itself. An interval of repose completely restores the power, obviously (to the mind of the Physiologist) by the renovation of the worn-out Brain-tissue, and by the purification of the Blood that has become charged with the products of its "waste."—The impairment of the Memory in Old Age commonly shows itself in regard to *new* impressions; those of the earlier period of life not only remaining in full distinctness, but even, it would seem, *increasing* in vividness, from the fact that the Ego is not distracted from attending to them by the continual influx of impressions produced by passing events. The extraordinary persistence of early impressions, when the Mind seems almost to have ceased to register new ones, is in remarkable accordance with the Law of Nutrition referred to in a previous paper. It is when the Brain is *growing*, that the *direction* of its structure can be most strongly and persistently given to it. Thus the Habits of Thought come to be formed, and those Nerve-tracks laid down which (as the Physiologist believes) constitute the Mechanism of Association, by the time that the Brain has reached its maturity; and the Nutrition of the organ continues to keep up the same mechanism, in accordance with the demands upon its activity, so long as it is being called into use. Further, during the entire period of vigorous Manhood, the Brain, like the Muscles, may be taking on some additional growth, either as a whole, or in special parts; new tissue being developed and kept up by the nutritive process, in accordance with the modes of action to which the Organ is trained. And in this manner a store of "impressions" or "traces" is accumulated, which may be brought within the "sphere of consciousness" whenever the right suggesting-strings are touched. But, as the Nutritive activity diminishes, the "waste" becomes more rapid than the renovation; and it would seem that, while (to use a Commercial analogy) the "old-established houses" keep their ground, those later firms whose basis is less secure, are the first to crumble away—the Nutritive activity, which yet suffices to maintain the *original* structure, not being capable of keeping the subsequent additions to it in working order. This *earlier* degeneration of *later*-formed structures is a general fact perfectly familiar to the Physiologist.

The effects of Disease and Injury on the Memory are so marvellous and diverse, that only a very general indication of them can be here given. Cases are very common, in which the form of impairment just spoken of as characteristic of Old Age shows itself to a yet greater extent; the Brain being so disordered by attacks of Apoplexy or Epilepsy (for example), that it seems altogether incapable of retaining any *new* impressions, so that the patient does not remember any thing that passes from day to day; while the impressions of events which happened *long before* the commencement of his malady recur with greater vividness than ever. The Memory of *particular classes of Ideas* is frequently destroyed; that, for example, of a certain Language, or of some other branch of Knowledge, or of the patient's domestic or social relations. Thus a case was recorded by Dr. Beattie, of a gentleman, who, after a blow on the head, found that he had lost his knowledge of Greek, but did not appear to have suffered in any other way. A similar case has been recently communicated to me, in which a lad, who lay for three days insensible, in consequence of a severe blow on the head, found himself, on recovering, to have lost all the Music he had learned, though nothing else had been thus "knocked out" of him. Again, Dr. Abercrombie relates a curious case, on the authority of an eminent medical friend, in which a surgeon who suffered an injury of his head by a fall from his horse, on recovering from his insensibility gave minute directions in regard to his own treatment, but was found to have lost all remembrance of having a wife and children; and this did not return until the third day. Similar losses of particular Languages, and other kinds of acquired knowledge, have been noted as the results of Fevers.

One of the most remarkable results of recent Pathological research has been, the discovery of the dependence of the condition termed *Aphasia*, or "loss of memory of words," upon malnutrition of a certain part of the Cerebrum; and the tracing of this malnutrition back to an interruption in the supply of Blood. In this curious Mental infirmity (which often begins to show itself before there is any other evidence of Cerebral disorder, but which is now recognized as a most serious indication of impending mischief), the subject either forgets the words he wants for expressing his ideas, or he uses *inappropriate* words in their place. It is obvious that he *knows* what he wants to express, but cannot recall the words in which to convey that knowledge to others. There is no paralysis of speech, for his articulation is quite unaffected; so that he can repeat the words he wants, if they are suggested to him by others. In a case formerly under my observation, the Aphasia went on gradually but very slowly increasing for three or four years; showing itself at first as to only a few out-of-the-way words, but gradually increasing until no intelligible language seemed to be left, except that of swearing, which came forth in a torrent when any restraint was put on the patient's bodily activity, which continued very energetic until near the close of life. In another case recently mentioned to me by a medical friend, who was a near connection of the patient, the disease ran its course in a few months. Cases of this kind almost invariably terminate in Apoplexy.—Now, it may be said that we have here only the evidence of *synchronous* disease of the Brain and disorder of the Mind; so that the *dependence* of the latter upon the former is not made out. But the very curious discovery was made a few years ago, by Dr. J. Hughlings Jackson, that the locally-impaired nutrition of the Brain in these cases is usually attributable to "embolism" of the middle meningeal artery, whereby the passage of blood through it is greatly impeded; this "embolism" consisting in the plugging of the artery by a fibrinous clot brought from the heart, where it has been produced by valvular disease. In the second of the cases just referred to, the usual brain-lesion having been found, and the middle meningeal artery having been examined, the *fons et origo* of the mischief was found to be, not "embolism," but a morbid deposit on the inner wall of the artery, producing a corresponding obstruction to the circulation. Looking, then, to the fact that *immediate* cessation of Mental activity is distinctly and unmistakably produced by the *entire* suspension of Blood-circulation through the Brain, how can the Physiologist refuse to recognize, in this *local* reduction of the Circulation, the Physical cause of that *limited* reduction of Psychical activity which so distinctly follows it?

But further, this singular fact, taken in connection with the recent great extension of our knowledge as to the local alterations in the calibre of the Arteries, which are produced through the "Vaso-motor" system of Nerves, obviously points to the probability that the *limited* but *transient* lapses of Memory just alluded to are due to a local reduction of the blood-supply in the part of the Cerebrum which ministers to the lost function; and that the *sudden* recovery which sometimes occurs is the result of the renewal of the normal circulation, through the giving way of the impacted clot, or the yielding of the spasmodically-constricted arterial wall.

Thus Dr. Rush, of Philadelphia, was acquainted with a person of considerable attainments, who, on recovering from a fever, was found to have lost all his acquired knowledge. When his health was restored, he began to apply himself to the Latin Grammar; and, while, one day, making *a strong effort* to recollect a part of his lesson, *the whole of his lost impressions suddenly returned to his remembrance*, so that he found himself at once in possession of all his former acquirements.—The like sudden restoration, after an equally sudden loss, occurred in another case in which all acquired knowledge was lost for *a whole year;* and in both the loss and the recovery there was clear evidence of strong *Emotional* excitement, which is well known to the Physiologist to have a most powerful control over the calibre of the Blood-vessels.

There is another class of familiar phenomena, which affords strong evidence of the dependence of the *recording process* upon Nutritive changes in the Brain. Every one is aware that what is rapidly learned —that is, merely committed to Memory—is very commonly forgotten as quickly, "one set of ideas driving out another." That thorough apprehension of what is learned, on the other hand, by which it is made (as it were) part of the Mental fabric, is a much slower process. The difference between the two is expressed by the colloquial term "cramming," as distinguished from "learning;" the analogy being obvious to the overloading the stomach with a mass of food too great to be digested and assimilated within a given time, so that a large part of it passes *out of* the body without having been applied to any good purpose *in* it. A part of this difference obviously consists in the formation of *Mental Associations* between the newly-acquired knowledge and that previously possessed; so that the new ideas become linked on with the old by "suggesting" chains. Such is especially the case, when we are applying ourselves to the study of any branch of knowledge, with the view of permanently mastering it; and here the element of *Time* is found practically to be very important. Thus, it is recorded of the late Lord St. Leonard's that, having (as Sir Edward Sugden) been asked by Sir T. F. Buxton what was the secret of his success, his answer was: "I resolved, when beginning to read Law, to make every thing I acquired *perfectly my own*, and never to go to a second thing till I had entirely accomplished the first. Many of my competitors read as much in a day as I read in a week; but, at the end of twelve months, my knowledge was as fresh as on the day it was acquired, while theirs had glided away from their recollection."—(*Memoirs of Sir T. F. Buxton*, chap. xxiv.) —In this Assimilating process, it is obvious that the new knowledge is (as it were) turned over and over in the Mind, and viewed in all its aspects; so that, by its coming to be not merely an *addition* to the old, but to *interpenetrate* it, the old can scrarcely be brought into the "sphere of consciousness," without bringing the new with it. But, from the considerations already adduced, it seems almost beyond doubt that the formation of this Associative *nexus* expresses itself in the Physical structure of the Brain, so as to create a mechanism whereby it is perpetuated so long as the Nutrition of the organ is normally maintained.

Another class of phenomena, now to be considered, seems to afford even more direct and cogent evidence of the dependence of Memory, in its simplest exercise, upon a *registering* process, that consists in some Nutritive modification of the Brain-tissue. In what we call "learning by heart"—which should be rather called learning by Sense, instead of by Mind—we try to imprint on our Memory a certain sequence of words, numbers, musical notes, or the like; the reproduction of these being mainly dependent upon the association of each *item* with that which follows it, so that the utterance of the former, or the picture of it in "the mind's eye," *suggests* the next. We see this plainly enough when children are set to learn a piece of poetry of which their minds do not take in the meaning; for the *rhythm* here affords a great help to the suggestive action; and nothing is more common than to hear words or clauses (transferred, perhaps, from some other part of the poem) *substituted for the right ones*, which are not only inappropriate but absolutely absurd in the lines as uttered.

So, again, if the child is at fault, he does not think of the *meaning* of the sentence, and of what is wanted to complete it; but "tries back" over the preceding words, that their *sound* may suggest that of the word he desiderates. So there are older persons, with whom the *pictured* remembrance of the words and phrases is more suggestive; as in a case to be presently cited.—Now, in these instances, it is a familiar fact that what is thus learned but once, however perfectly, soon "goes out of the head," being only fixed there by continual repetition; and, as the Memory we are now considering is rather *Sensorial* than *Ideational*, this fact is confirmatory of the doctrine that seems probable on other grounds, of the superior (if not the exclusive) persistence of the latter. We seem distinctly able to trace the action of the *recording process* in this elementary form of Memory, in the help given in the "learning by heart" of a task, by repeating it the last thing at night; for every school-boy, who has to commit to memory fifty lines of Virgil, knows very well that, if he can "say them to himself," even slowly and bunglingly, just before going to sleep, he will be able to recite them much more fluently in the morning. The Physiologist sees here an obvious indication that the *recording process* has gone on without interruption by new impressions on the Sensorium, so that there has been *time* for the *fixation* of the last by Nutritive change. We have, indeed, a remarkable *converse* phenomenon, in the rapid fading away of a Dream, which, at the moment of waking, we can reproduce with extraordinary vividness; for the "trace" left by its details is soon obliterated by the new and stronger impressions made on our waking Consciousness, so that, a few hours afterward, we are often unable to revive more than the general outline of the Dream—and perhaps not even that, unless we have told it to another when it was fresh in our minds, of which act a "trace" would be left.

There are two classes of persons who are professionally called upon for great *temporary* exercises of Memory, viz., Dramatic Performers and Barristers. An actor, when about to perform a new "part," not only commits it to memory, but "studies" it, so as to make it part of himself; and all really *great* actors identify themselves for the time with the characters they are performing. When a "part" has once been thoroughly mastered, the performer is usually able to go through it, even after a long interval, with very little previous preparation. But an actor is sometimes called upon to take a new "part" at very short notice; he then simply "learns it by heart," and speedily forgets it. A case of this kind is cited by Dr. Abercrombie, as having been the experience of a distinguished actor, on being called on to prepare himself in a long and difficult part, at a few hours' notice, in consequence of the illness of another performer. He acquired it in a very short time, and went through it with perfect accuracy; but immediately after the performance forgot it to such a degree that, although he performed the character for several days in succession, he was obliged every day to prepare it anew—not having time to go through the process of "studying" it, to which Mrs. Siddons used to give weeks or even months. When questioned respecting the mental process which he employed the first time he performed the part, he said that he entirely lost sight of the audience, and seemed to have nothing before him but the pages of the book from which he had learned it; and that, if any thing had occurred to interrupt this illusion, he should have instantly stopped.—(*Inquiry into the Intellectual Powers*, fifth edition, p. 103.)

In the case of Barristers, who are called upon to "get up" the "briefs" which are supplied to them, to master the facts, to apply to them the principles of Law, and to present them in the Court in the form which they deem most advantageous to the "cause" they have undertaken to plead, the very highest faculties of mind are called into active exercise; but, in consequence, it would seem, of the want of previous connection with the "case" (of which they know nothing but what is set down in their "brief"), and of the complete cessation of that connection as soon as the decision has been given, they very commonly "forget all about it" so soon as they have transferred their Attention to their next brief. A curious instance of this kind was mentioned to the writer a few years ago by an eminent Barrister (since elevated to the Judicial Bench), whose great scientific attainments led to his being frequently employed in Patent-cases. A "heavy" case of this kind was placed in his hands, and he was reminded of having been engaged by the same parties in the same "case" when it had been first brought to trial about a year previously. He had not the slightest remembrance of its having ever been before him; none of the particulars of it seemed familiar to him; and he was only convinced that he really *had* taken part in the previous trial by finding the record of his engagement in his Fee-book. Even when he came to "get up" the case again, no remembrance of his former attention to it came within his "sphere of consciousness."

It seems, then, to admit of question whether *every thing* that passes through our Minds thus leaves its impress on their Material instrument; and whether a somewhat too extensive generalization has not been erected on a rather limited basis. For the doctrine of the indelibility of Memory rests on the spontaneous revival, under circumstances indicative of some change in the Physical condition of the Brain, of the long-dormant "traces" left by such former impressions as are referable to one or other of the three following categories: 1. States of Consciousness as to places, persons, language, etc., which were *habitual* with us in early life, and which were, therefore, likely to have directed the *growth* of the Brain; 2. Modes of Thought in which the formation of Associations largely participates, and which are likely to have modified the course of its *maintenance* by Nutrition after the attainment of maturity; or 3. Single Experiences of peculiar force and vividness, such as are likely to have left very decided "traces," although the circumstances of their formation were so unusual as to keep them out of ordinary associational remembrance. Thus a remarkable case is mentioned by Dr. Abercombie ("Intellectual Powers," fifth edition, p. 149) of a boy, who, at the age of four years, underwent the operation of trepanning, apparently in a state of perfect stupor, and who, after his recovery, retained no recollection either of the accident by which his skull was fractured, or of the operation, yet who, at the age of fifteen, during the delirium of fever, gave his mother an account of the operation and of the persons who were present at it, with a correct description of their dress, and other minute particulars of which it was scarcely possible that he could have acquired the knowledge from verbal information. Here it would seem that all the Mental power the patient then had must have been concentrated upon the impressions made upon his Sensorium, which were thus indelibly branded (as it were) upon his Organism; but that these "traces," being soon covered up by those resulting from the new experiences of restored activity, remained outside the "sphere of consciousness" until revived by a Physical change which reproduced the images of the objects that had left them.

The direct causal relation of Physical conditions to Mental states may be made still more clear by following out into some detail the phenomena of that peculiar form of Intoxication which is produced by *Hashish*—a preparation of Indian hemp used in the Levant for the purpose of inducing what is termed the *fantasia.* The action of this drug was very carefully studied some years ago by M. Moreau, Physician to the Bicêtre, who had given great attention to the Psychology of Insanity, and whose special object was to throw light upon that subject by experimenting upon what he termed its artificial production. His treatise, "Du Hachisch, et de l'Aliénation Mentale" (Paris, 1845), is one which deserves the attentive study of such as desire to base their Psychology upon a comprehensive survey of facts.

One of the first appreciable effects of the *Hashish*, as of other Intoxicating agents, is the gradual weakening of that power of *Volitionally* controlling and directing the current of thought, the possession of which characterizes the vigorous mind. The individual feels himself incapable of fixing his attention upon any subject; the continuity of his thoughts being continually drawn off by a succession of disconnected ideas, which force themselves (as it were) into his mind, without his being able in the least to trace their origin. These speedily engross his attention, and present themselves in strange combinations, so as to produce the most impossible and fantastic creations. By a strong effort of the Will, however, the original thread of the ideas may still be recovered, and the interlopers may be driven away; their remembrance, however, being preserved, like that of a dream recalling events long since past. These lucid intervals progressively become shorter in duration, and can be less frequently procured by a voluntary effort; for the internal tempest becomes more violent, the torrents of disconnected ideas are so powerful as completely to arrest the attention, and the mind is gradually withdrawn altogether from the contemplation of external realities, being conscious only of its own internal workings. There is always preserved, however, a much greater amount of "self-consciousness" than exists in ordinary Dreaming; the condition rather corresponding with that in which the sleeper knows that he dreams, and, if his dream be agreeable, makes an effort to prolong it, being conscious of a fear lest he should by awaking cause the dissipation of the pleasant illusion.

It is another characteristic of the action of *hashish* that the succession of ideas has *at first* less of incoherence than in ordinary Dreaming, and the ideal events do not so far depart from possible realities; the disorder of the mind being at first manifested in errors of sense, in false convictions, or in the predominance of one or more extravagant ideas. These ideas and convictions are generally not altogether of an imaginary character, but are rather *suggested* by external impressions, these impressions being erroneously interpreted by the perceptive faculties, and giving origin, therefore, to fallacious notions of the objects which excited them. It is in that more advanced stage of the "fantasia' which immediately precedes the complete withdrawal of the mind from external things, and in which the self-consciousness and power of the Will are weakened, that this perverted impressibility becomes most remarkable, more especially as the general excitement of the Feelings causes the erroneous notions to have a powerful effect in arousing them.

"We become," says M. Moreau, "the sport of impressions of the most opposite kind; the continuity of our ideas may be broken by the slightest cause. We are turned, to use a common expression, by every wind. By a word or a gesture our thoughts may be successively directed to a multitude of different subjects with a rapidity and a lucidity which are truly marvellous. The mind becomes possessed with a feeling of pride corresponding with the exaltation of its faculties, of whose increase in energy and power it becomes conscious. It will be entirely dependent on the circumstances in which we are placed, the objects which strike our eyes, the words which fall on our ears, whether the most lively sentiments of gayety or of sadness shall be produced, or passions of the most opposite character shall be excited, sometimes with extraordinary violence; for irritation shall rapidly pass into rage, dislike to hatred and desire of vengeance, and the calmest affection to the most transporting passion. Fear becomes terror, courage is developed into rashness, which nothing checks, and which seems not to be conscious of danger, and the most unfounded doubt or suspicion becomes a certainty. *The Mind has a tendency to exaggerate every thing;* and the slightest impulse carries it along. Those who make use of the *Hashish* in the East, when they wish to give themselves up to the intoxication of the *fantasia*, take care to withdraw themselves from every thing which could give to their delirium a tendency to melancholy, or excite in them any thing else than feelings of pleasurable enjoyment; but they profit by all the means which the dissolute manners of the East place at their disposal."

The disturbance of the Perceptive Faculties is remarkably shown in regard to Time and Space. Minutes seem hours, and hours are prolonged into years; and at last all idea of Time seems obliterated, and the past and present are confounded together. M. Moreau mentions as an illustration, that on one evening he was traversing the passage of the Opera when under the influence of a moderate dose of *Hashish.* He had made but a few steps, when it seemed to him as if he had been there two or three hours; and, as he advanced, the passage appeared to him interminable, its extremity receding as he pressed forward. But he gives another more remarkable instance. In walking along the Boulevards, he has frequently seen persons and things at a certain distance presenting the same aspect as if he had viewed them through the large end of an opera-glass—that is, diminished in apparent size, and therefore suggesting the idea of increased distance. This erroneous perception of Space is one of the effects of the *Amanita muscaria*, an intoxicating Fungus used by the Tartars; a person under its influence being said to take a jump or a stride sufficient to clear the trunk of a tree when he wishes only to step over a straw or a small stick. Such erroneous perceptions are common enough among Lunatics, and become the foundations of fixed illusions; while in the person intoxicated by *Hashish* there is still a certain consciousness of their deceptive character.

Though all the Senses appear to be peculiarly impressible in this condition, yet that of Hearing seems the one through which the greatest influence may be exerted upon the Mind, especially through the medium of musical sounds. The celebrated artist, M. Théodore Gaultier, describes himself as hearing sounds from colors, which produced undulations that were perfectly distinct to him. But he goes on to say that the slightest deep sound produced the effect of rolling thunder; his own voice seemed so tremendous to him that he did not dare to speak out for fear of throwing down the walls, or of himself bursting like a bomb; more than five hundred clocks seemed to be striking the hour with a variety of tones, etc., etc. Of course, those individuals who have a natural or an acquired "musical ear" are the most likely to be influenced by the concord or succession of sweet sounds; and in such the simplest music of the commonest instrument, or even an air sung by a voice in a mediocre style, shall excite the strongest emotions of joy or melancholy, according as the air is cheerful or plaintive; the mental excitement being communicated to the body, and being accompanied with muscular movements of a semi-convulsive nature. This influence of music is not merely sensual, but depends, like that of other external impressions, upon the associations which it excites, and upon the habitual disposition to connect it with the play of the Imaginative faculties.

It is seldom that the excitement produced by the Hashish fixes itself upon any particular train of Ideas, and gives rise to a settled delusion; for in general one set of ideas chases another so rapidly, that there is not time for either of them to engross the attention of the intellect; more especially since (as already remarked) there is usually such a degree of self-consciousness preserved throughout, as prevents the individual from entirely yielding himself up to the suggestions of his ideal faculties. M. Moreau mentions, however, that on one occasion, having taken an overdose, and being sensible of unusual effects, he thought himself poisoned by the friend who had administered it, and persisted in this idea in spite of every proof to the contrary—until it gave way to another, namely, that he was dead, and was about to be buried; his self-consciousness, however, being yet so far preserved that he believed his body only to be defunct, his soul having quitted it. But when this is altogether suspended, as it seems to be by a larger dose, the erroneous ideas become transformed into convictions, taking full possession of the mind; although sudden gleams of common-sense burst through the mists of the imagination, and show the illusive nature of the pictures which the "Internal Senses" have impressed on the Sensorium. All this—as every one knows, who has made the phenomena of Insanity his study—has its exact representation in the different stages of Mental Derangement; the illusive ideas and erroneous convictions being in the first instance capable of being dissipated by a strong effort of the Will, gradually exerting a stronger and stronger influence on the general current of Thought, and at last acquiring such complete mastery over it that the Reason cannot be called into effective operation for the correction of the perverted Ideas.

Here, then, we have an extraordinary *exaltation* of the Automatic action of the Brain, manifesting itself in the rapidity and intensity of the current of Thought; while the controlling power of the Will is not only relatively, but *absolutely* reduced. And this modification of the normal form of mental activity is clearly referable to the perversion of the normal action of the Blood upon the Brain, which is due to the introduction of a new Physical agent into the former. The production of errors of Perception, arising from the tendency to *magnification* of the impressions actually made on the senses, is a peculiarly interesting feature of this perversion; which is clearly a *mental* misinterpretation, not at all corresponding to the mere double vision of the drunken man, which is an error of *sense* arising from the temporary want of adjustment of the axes of the eyes. And with this magnification there is connected a sentiment of *happiness* which attends all the operations of the mind.

"It is really *happiness*," says M. Moreau, "which is produced by the Hashish; and by this I imply an enjoyment entirely Moral, and by no means sensual, as we might be induced to suppose. This is surely a very curious circumstance, and some remarkable inferences might be drawn from it; this, for instance, among others—that every feeling of joy and gladness, even when the cause of it is exclusively moral—that those enjoyments which are least connected with material objects, the most spiritual, the most ideal—may be nothing else than sensations purely physical, developed in the interior of the system, as are those procured by the Hashish. At least, so far as relates to that of which we are internally conscious, there is no distinction between these two orders of sensations, in spite of the diversity in the causes to which they are due; for the Hashish-eater is happy, not like the gourmand or the famished man when satisfying his appetite, or the voluptuary in gratifying his amative desires; but like him who hears tidings which fill him with joy, like the miser counting his treasures, the gambler who is successful at play, or the ambitious man who is intoxicated with success."

Most persons will be able to recall analogous states of exhilaration, and the reverse condition of depression, in themselves; the former being characterized by a feeling of general well-being, a sentiment of pleasure in the use of all the bodily and mental powers, and a disposition to look with enjoyment upon the present, and with hope to the future; while in the latter state there is a feeling of general but indefinable discomfort. Every exertion, whether Mental or Bodily, is felt as a burden; the present is wearisome, and the future is gloomy. These, like all other phases of Human Nature, are faithfully portrayed by Shakespeare. Thus *Romeo* gives expression to the feelings inspired by the first state:

> "My bosom's lord sits lightly in his throne;
> And, all this day, an unaccustomed spirit
> Lifts me above the ground with cheerful thoughts."
> (*Romeo and Juliet*, V., 1.)

While the reverse state is delineated by *Hamlet* in his familiar soliloquy:

> "I have of late—but wherefore I know not—lost all my mirth, foregone all custom of exercises; and, indeed, it goes so heavily with my disposition, that this goodly frame, the earth, seems to me a sterile promontory; this most excellent canopy, the air, look you—this brave o'erhanging firmament, this majestic roof fretted with golden fire, why it appears no other thing to me than a foul and pestilent congregation of vapors."—(*Hamlet*, II., 2.)

In the conditions here referred to, the same feelings of pleasure and discomfort attend *all* the operations of the mind—the merely Sensational and the Intellectual. In the state of exhilaration, we feel a gratification from sensations which at other times pass unnoticed, while those which are usually pleasurable are remarkably enhanced; and in like manner, the trains of Ideas which are started being generally attended with similar agreeable feelings, we are said to be under the influence of the pleasurable or elevating Emotions. On the other hand, in the state of depression we feel an indescribable discomfort from the very sensations which before produced the liveliest gratification; and the thoughts of the past, the present, and the future, which we before dwelt on with delight, now excite no feelings but those of pain, or at best of *insouciance.*

Now, there are many persons in whom these opposite Emotional states are induced by Meteorological conditions; the one by a dry, clear, bright atmosphere; the other by that close, damp, "muggy" state of the air, which seems to lay a "wet blanket" upon all their enjoyment, both bodily and mental. And precisely the same depressing influence is often experienced from deficient action of the liver, causing an accumulation of the materials of bile in the blood; and it is just as apparent to the Physician that the elimination of these by appropriate remedies, so as to restore the Blood to its normal purity, thereby removes the Moral *depression*, as it is that the introduction of a minute quantity of Hashish into the Blood produces a Moral *exaltation.*

In these days of eager competition, again, it is extremely common for a psychical state to be induced by the overtasking of the Brain, which every intelligent medical practitioner recognizes as essentially physical in its origin, but which yet manifests itself chiefly in moral, and not unfrequently, also, in intellectual perversion. The excess of activity is followed, as its natural result, by a state of depression; in which the subject of it looks at every thing, past, present, and future, in a gloomy light, as through a darkened glass. His whole life has been evil; he has brought ruin on his affairs; his dearest friends are in league to injure him. At first this moral perversion extends itself only to a misinterpretation of actual occurrences, which only differs in degree from that which we observe in persons of a morose temper. But, with the advance of the disorder, the mind dwells on its own morbid imaginings, till they come to take the place of actual facts; and in this way *hallucinations* are generated—i. e., creations of the imagination, which are accepted as real occurrences. Now, here there is no primary intellectual perversion; the reasoning powers are not disturbed; the patient can discuss with perfect sanity any question that does not touch his morbid feelings; but the representations shaped by his own mind, under the influence of these feelings, being received as truths to the exclusion of his common-sense, all his actions are based on those erroneous data. This condition is merely an intensification of that just described; and the Physician can no more doubt that it depends upon an unhealthy condition of the bodily frame, than that the delirium of fever and the fantasia of Hashish are dependent upon the presence of a poison in the blood.

The Psychologist who neglects such phenomena as these, merely because the inferences drawn from them by the Physiologist have a dangerous flavor of "materialism," seems to me just as blameworthy as the Physiologist who ignores the facts of consciousness, when they do not happen to fit in with his own conclusions. The true Psychologist is he who lays the foundations of his science broad and deep in the *whole* constitution of the individual man, and his relations to the World external to him; and aims to build it up with the materials furnished by Experience of every kind, mental and bodily, normal and abnormal; ignoring no fact, however strange, that is attested by valid evidence, and accepting none, however authoritatively sanctioned, that will not stand the test of thorough scrutiny.

It is very easy, and doubtless very pleasant, to dispose of "Cerebration" by a sneer; but those who do so may be fairly called upon in the first place to acquaint themselves with a class of facts which they have never studied; and, when they *have* examined them, may be challenged to give some better and more scientific *rationale* of them than that here offered. I should myself rejoice to welcome *any* new light that metaphysics can throw upon such questions as the following:

1. What other than "Physical Antecedents" excite those states of Consciousness which we call *Sensations*, and the Pleasure and Pain associated with them?

2. Does not all Psychological as well as Physiological probability point to the identity of the Sensorial instrumentality through which we become conscious (1) of a *present* Impression, and (2) of a *remembered* Sensation?

3. If, then, a Visual *perception* be immediately dependent on a Physical change in the Sensorium, excited (through the optic nerve) by a Physical change in the Retina, is it not probable that a Visual *conception* depends on a corresponding Physical change in the Sensorium, called forth (through the "nerves of the internal senses") by a Physical change in the cortical substance of the Cerebrum?

4. As *Sensational* Consciousness can be excited by "Physical Antecedents," why should not *Ideational* and *Emotional?*

5. Is there not Psychological as well as Physiological evidence that the excitement of the Ideational consciousness is the result of a *series* of Physical changes taking place in the Cerebrum, as the action of a Mechanism created by its preformed Habits? In what other way are the facts (admitted by Psychologists of all schools) to be accounted for, which indicate the suggestion of one Idea by another through a chain of Associations, some links of which lie outside the "sphere of consciousness?"

6. Is it conceivable that such an oft-recurring phenomenon as the loss of some branch of acquired Knowledge, after a blow on the head or a fever, is a mere *coincidence?* If not, on what other hypothesis than that of "Physical antecedence" can the blow be the *cause* of this Mental *effect?*

7. Is there not as much evidence that "Physical Antecedents" may produce *Moral* Pleasure and Pain, as that they produce *Sensorial* Pleasure and Pain?

8. If in *any* case we admit Physical antecedence as the Cause (in the ordinary language of Science) of Mental Phenomena, why not in

every case of *automatic* Mental activity?—whether this be left altogether uncontrolled, or be in subjection to the will.

9. When a series of Physical sequences comes to be established by the Habitual action of the Cerebrum in particular modes directed or permitted by the Will, is it not consonant to all Physiological probability that the *tendency* to similar sequences should be hereditarily transmitted, like the tendency to bodily habits?—*Contemporary Review.*

THE LONGEVITY OF TREES.

By ELIAS LEWIS.

IN the vegetable world, limits of growth and life are strangely diversified. Multitudes of forms mature and perish in a few days or hours; while others, whose beginning was in a remote antiquity, have survived the habitual period of their kind, and still enjoy the luxuriance of their prime. Some species of unicellular plants are so minute that millions occur in the bulk of a cubic inch, and a flowering plant is described by Humboldt, which, when fully developed, is not more than three-tenths of an inch in height. On the other hand, we have the great *Sequoia*, whose mass is expressed by hundreds of tons, and specimens of the *Eucalyptus*, growing in the gulches of Australia, surpass in height the dome of St. Peter's.

Some of the Fungi mature between the setting and rising of the sun, while the oak at our door, which awakens the memories of our childhood, has not perceptibly changed in bulk in half a century. Trees grow more slowly as they increase in age. Nevertheless, it is certain that growth continues while they continue to live. The development of foliage implies interstitial activity and organization of new material. In its vital processes there is little expenditure of force or waste of substance. Its functions are essentially constructive, and its growth and age are apparently without limits, excepting such as arise from surrounding conditions. Thus many trees represent centuries, and have a permanence that is astonishing and sublime. Travellers stand awe-struck before the monuments which for forty centuries have kept watch by the Nile, but the oldest of these may not antedate the famous dragon-tree of Teneriffe. It is not surprising that the ancients considered trees "immortal," or, as "old as Time."

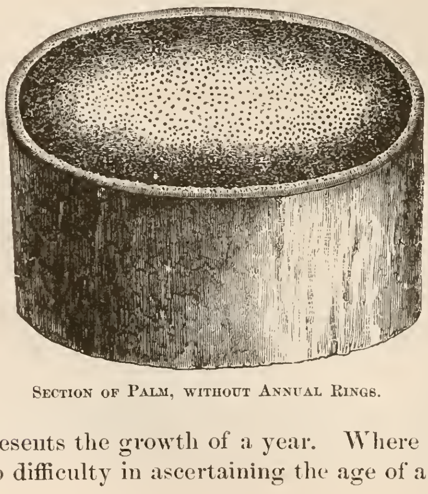
But, if the life of the tree is continuous, its leaves—the organs of its growth—have their periods of decay, and are types of mortality. The life of man is likened to the "leaf that perishes." In an animal, the vital processes are carried on by a single set of organs, the impairment of which limits the period of its life. With the tree, decay of the organs is followed by constant renovation, and the foliage which covers it the present summer is as new and as young as that which adorned it a hundred or a thousand years ago. Trees which shed their leaves annually, or at longer intervals as do the evergreens,

Fig. 1.

Section of Trunk of Fir-Tree, showing the Annual Rings of Growth.

grow by formation of new wood in layers upon their outer surface, and just beneath the bark. These constitute the class *Exogens*, or outside growers, as shown in Fig. 1. This plate, with others used to illustrate this article, are from Figuier's "Vegetable World," and have been placed at our disposal by the publishers of that interesting work.

Fig. 2.



Section of Palm, without Annual Rings.

A layer represents the growth of a year. Where these are accessible, there is no difficulty in ascertaining the age of a tree, or the rate of its growth; and the rate thus ascertained may be applied to other trees of its kind whose diameter is known, although its woody layers be inaccessible. In this way the age of many trees has been estimated. The relation between the age of a tree and its annual rings was first noticed and applied by Montaigne, in 1581.

Fig. 3.

Palm-Trees.

But this method of ascertaining a tree's age does not apply to the class *Endogens*, in which the growth is internal, as shown in Fig. 2.

Fig 4.

Oriental Plane Tree in the Valley of Bujukdere, near Constantinople.

Great Chestnut of Mount Etna.

In these a hard, inflexible shell forms around the inner portions, the tree increases little in diameter, and no woody layers are found. To this class belong the Palms, of which Fig. 3 is an illustration. The age of this class of trees is estimated by comparing specimens with others whose age is known, or from an ascertained rate of growth. The oldest palms may not exceed five centuries, and their average period is probably less than 200 years. The height of the tallest of the species is said to be 192 feet. Trees growing in dense forests are comparatively short-lived, and attain less bulk than those in open places, where side-branches develop in the unobstructed rays of the sun. In similar conditions the age and dimensions attained by trees of each species are tolerably constant. Thus the average period of oaks and pines may be 300 or 400 years; but the exceptions are so numerous and wonderful, that we shall present in this paper a few of the most interesting and best-authenticated instances.

Of the white-pines, once the glory of the New England forests, we are not aware that any have been found more than 430 years old. Nor have we any oaks of extraordinary age. The Charter-oak at Hartford may have been a small tree at the first settlement of New England. The Wadsworth oak, at Geneseo, New York, is said to be five centuries old, and 27 feet in circumference at the base. The massive, slow-growing live-oaks, of Florida, are worthy of notice, on account of the enormous length of their branches. Bartram says: "I have stepped 50 paces in a straight line from the trunk of one of these trees to the extremity of the limbs."

The oaks of Europe are among the grandest of trees. The Cowthorpe oak is 78 feet in circuit at the ground, and is at least 1,800 years old. Another, in Dorsetshire, is of equal age. In Westphalia is a hollow oak, which was used as a place of refuge in the troubled times of mediæval history.

The great oak at Saintes, in Southern France, is 90 feet in girth, and has been ascertained to be 2,000 years old. This monument, still or recently flourishing, commemorates a period which antedates the first campaign of Julius Cæsar!

The oriental plane-tree is noted in Eastern countries for its size and longevity. Fig. 4 represents one near Constantinople, which is 100 feet high, and 150 feet in circuit. It has been suggested that this is really a group of trees originally planted near together for their shade. The figure, however, hardly confirms that opinion, and many trees of this species are mentioned by travellers not greatly inferior to this one in dimensions.

Most of the old plane-trees are hollow, their tops being sustained by wood of recent growth. In this respect an exogenous tree resembles a coral-reef, where the vitality and growth are at the surface only.

Of chestnuts, we have the famous one at Tortworth, in Glou-

Fig. 6.

Cedar of Lebanon.

cestershire, England, which was a large tree in the reign of King Stephen, and is over 1,000 years old. Fig. 5 represents the "Great Chestnut of Mount Etna," consisting, at present, of what appears to be several trees, fragments of the original one. By a writer in the *North American Review*, for July, 1844, these are supposed to be shoots from, rather than portions of, the old tree.

Jean Houel, who examined the trees, says "they are portions of one tree." By removing the soil, the outer rim of the tree has been found, and the circumference ascertained to be 175 feet. Other chestnuts near this are in girth 64, 70, and 72 feet respectively.

The lime or linden, in Europe, is an important tree. Those in the town of Morat are celebrated in the history of Switzerland. One was planted in 1476 to commemorate the defeat of the Burgundians, under Charles the Bold; the other was a noted tree at the time of the battle, and is now near nine centuries old. But, equally famous is the one at Würtemberg, called the "Great Linden," six centuries ago. It is, probably, 1,000 years old, and measures 35½ half feet in girth. Four and a half centuries ago its branches were supported by 67 columns of stone, now increased to 106, many of which are "covered with inscriptions."

The well-known olive-tree is associated with our most cherished recollections. There is an old one near Nice, 24 feet in girth, regarded by the inhabitants with great interest. Those on the Mount of Olives may be contemporary with the Christian era. They are known to have been in existence in 1217, when the Turks captured Jerusalem.

The evergreen cypress, long celebrated for its longevity, is abundant in the burial-grounds of Eastern nations, and, from it dark, dense foliage, forms an impressive feature of Oriental landscapes. In the Palace Gardens of Granada are cypresses said to be 800 years old; and there is one at Somma, in Lombardy, proved by authentic documents "to have been a considerable tree 40 years before the Christian era." Of this family of trees is our well-known white cedar, specimens of which, exhumed from the meadows on the coast of New Jersey, had from 700 to 1,000 rings of wood solid and fragrant as if of recent growth.

The cedars of Lebanon are often referred to in the Sacred Writings. The present trees are, we believe, seven large ones, with many of smaller growth, situated in an elevated valley of the Lebanon Mountains, 6,172 feet above the Mediterranean. The valley is surrounded by peaks of the mountains, which rise 3,000 feet higher, and are covered with snow. Fig. 6 may give some idea of their massive grandeur. De Candolle supposes the oldest are 1,200 years old, but no sections of their wood have been examined to determine their age. The cedar is known to grow slowly, as does the North American or bald cypress, which we will next notice. This tree is common in our

Fig. 7.

Sequoia Gigantea, of California.

Southern States, and its rate of growth has been determined. On the Mexican table-lands its growth and antiquity are immense.

The "Cypress of Montezuma," near the city of Mexico, is 44 feet in girth, and its age is estimated at upward of twenty centuries. In the church-yard of Santa Maria del Tule, in the Mexican State of Oaxaca, is a cypress which "measures 112 feet in circuit, and is without sign of decay." At Palenque are cypresses growing among the ruins of the old city, whose streets they may have shaded in the days of its pride. By the usual methods, the writer in the *North American Review* calculates the age of the cypress at Santa Maria del Tule at 5,124 years, or, if it grew as rapidly during its whole life as similar trees grow when young, it would still be 4,024 years old.

The yew has long been used in Great Britain as an adornment of places of sepulture, and is often referred to in English literature:

> "Beneath these rugged elms, that yew-tree's shade,
> Where heaves the turf in many a mouldering heap."

This tree, of almost imperishable wood, is indigenous to Great Britain. De Candolle ascertained its rate of growth, and concluded that individual specimens are of great antiquity. There is a yew at Ankerwyke House, older than *Magna Charta*. It was an old and celebrated tree when King John met the barons at Runnymede, in 1215, and its age is upward of eleven centuries; but the yews of Fountain's Abbey and the Darley yew are from three to five centuries older than this. In Fortingal Church-yard, Perthshire, is a yew 18 feet in diameter, through decayed portions of which funeral processions pass on their way to the grave. The age of this tree is estimated at 1,800 years. But of greater antiquity is the one described by Evelyn, which stood in Braborne Church-yard, in Kent. It measured 59 feet in girth, and was believed to be 2,500 years old. This tree, which has long disappeared, was probably contemporary with the founding of Rome. The growth and decline of a great empire was spanned by the duration of a single life.

More immense in bulk, but perhaps not older than these living monuments, are the pines of Oregon and the *Sequoias* of California. Mr. Douglas counted 1,100 annual layers in a Lambert pine, and 300 feet is not an unusual height for the Douglas spruce. Hutchings states that a *Sequoia*, which was blown down and measured by him, was 435 feet in length. It was 18 feet in diameter 300 feet from the ground. Scientific observation has connected with these trees an interest equal to that awakened by their size and age. Our most distinguished botanist, Prof. Gray, has shown that the *Sequoias*, now growing on a limited area, had formerly a wide distribution, and are lineal descendants from ancestral types which flourished at least as far back in geologic time as the Cretaceous age. The descent has been with modifications furnishing an important link in the

Fig. 8.

Dragon Tree of Teneriffe

chain of evidence which establishes the derivative origin of specific forms.

Prof. Gray thinks the age of the oldest living *Sequoia* may be about 2,000 years, and remarks: "It is probable that close to the heart of some of the living trees may be found the circle which records the year of our Saviour's nativity." Fig. 7 is a representation of the *Sequoia*.

The sacred banian, before noticed, is familiar to every reader. Its main trunk attains a diameter of from 20 to 30 feet, and its enormous roof of foliage may shelter the inhabitants of a considerable village. The pendent branches are really roots, which, on reaching the ground, penetrate it and form trunks. These correspond with the outer layers of wood in an oak or a pine, and sustain the top, although the original trunks decay and disappear.

The dragon-tree of Orotava, on the island of Teneriffe, is a well-known and historic tree. Our representation of it (Fig. 8) is from a drawing made in 1776. Twice during the present century it has been dismantled by storms. It is but 69 feet high, but is 79 feet in circumference. So slow is its growth that its diameter had scarcely changed in 400 years. Recently it bore flowers and luxuriant foliage, as it may have done before the "isles of the Western Ocean," on one of which it was growing, were a dream in the Grecian mythology.

The baobab, or monkey bread-fruit, is the last we can notice of the ancient trees. It was first described by a Venetian traveller in 1454. Fig. 9 is from a photograph of one on the west coast of Africa. These trees are found, however, in nearly all portions of that country south of the Desert, everywhere an imposing feature of the landscape, and objects of regard if not of reverence by the natives. In the rainy season they are in full luxuriance, and are covered with cup-shaped flowers six inches in diameter. The trunks grow from 20 to 60 feet high, but are sometimes 100 feet in circuit at the ground. The baobabs, like most other trees, grow rapidly when young, but slowly when old. Recent estimates attribute to some of the oldest a period of 3,000 years. This is scarcely more than one-half the age assigned to them by early writers.

In 1832 a baobab was transplanted into a garden at Caraccas, which grew as much in 40 years as would have required 100 years by early estimate. An account of this tree is published in *Natur und Leben*, No. 1, 1873.

By the native town of Shupanga, near the Zambesi, in Eastern Africa, is a venerable baobab, beneath which is the grave of Mrs. Livingstone.

Such, briefly, are some of the great living monuments of the vegetable kingdom. In longevity they are in striking contrast with higher types of life. Fixed to a single spot, the tree is what it is because of the forces which act upon it. It is a monument of accumulated and

Fig. 9.

The Baobab, or Monkey Bread-fruit Tree.

concentrated force. Transmuted sunlight is in all its fibres, and who shall estimate the dynamic work which has been expended in its structure?

Dr. Draper observes that "the beat of a pendulum occupies a second of time; divide that period into a million of equal parts, then divide each of these brief periods into a million of other equal parts, a wave of yellow light during one of the last small intervals has vibrated 535 times. Yet that yellow light has been the chief instrument in building the tree." In the delicate texture of its leaves it has overcome molecular force; it has beaten asunder the elements of an invisible gas, and inaugurated a new arrangement of atoms. The old dragon-tree represents forty centuries of this dynamic work—a sublime monument reared without toil by the silent forces of Nature!

In the outer air it has awakened every note of sound, from the softest monotone to the rhythmic roar of the tempest; but in its inner chambers has been a murmur and music of life in the ceaseless movement of fluids and marshalling of atoms, as one by one they take their place in the molecular dance, which eludes the dull sense of hearing, and becomes obvious only in results. The veil which hides these ultimate processes of life has not yet been lifted, and Science pauses in waiting before it, but only waits.

EARLY HINDOO MATHEMATICS.

By Prof. EDWARD S. HOLDEN,

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THERE is a certain fascination in our scanty knowledge of the elder nations of the earth, which is due quite as much to their chronological position as to the intrinsic interest of their doings and sayings; and it owes not a little of its keenness to the very scantiness of that knowledge.

We are continually told that this is a practical century; that we are utilitarians in the strictest sense; that there is no romantic faculty left to us; that we are apt to scorn all knowledge which has not a direct practical bearing on the daily life and interests of us all. How can we believe this when we would so eagerly hear of the autonomy of the Aztecs, and while we care so little for modern Chili, for example?

We can speak with more interest of Karnac than of Bogotá, and a mummy is dearer to us than a Mongolian. We require our thoughts to be suggested sometimes by an age of old and quaint habits, of strange people with stranger gods. In our busy life, it is a relief to turn to the Hindoo, who could spare the time "to sit beneath the tree and contemplate his own perfections," or to the Egyptian who evolved pyramids, and obelisks, and avenues of sphinxes, out of his infinite leisure.

There are always "the complaining ones," for whom the times are stale, who would lament with Sir Thomas Browne that "mummy is become merchandise, Mizraim cures wounds, and Pharaoh is sold for balsams;" but they forget that the great nineteenth century buys its mummies in order to have a good look at them, and that it studies the Rosetta Stone out of pure interest, and to make no money.

But the real interest of former ages is the study of their manner of thought. We study *what* they thought to determine *how* they thought it. We have an immense and vague curiosity to connect our minds with the minds of long ages ago. Half the fascination of Darwin, Tylor, Lubbock, and Wilson, is from this cause.

It piques us to know that, sixteen hundred years before our era, there was a poet who sang:

> "Like as a plank of drift-wood
> Tossed on the watery main,
> Another plank encounters,
> Meets—touches—parts again;
> So, tossed, and drifting, ever
> On life's unresting sea,
> Men meet, and greet, and sever,
> Parting eternally." [1]

This surely is not the verse of a primitive people; these are not the feeble lispings of the infants of our race; did it not require *time* to accustom the Hindoo mind to similes as complex as these? This verse would not seem childish if Tennyson had written it; it appeals to as deep a consciousness as Coleridge's "Hymn in the Vale of Chamounix," and would even bear comparison with the "Peter Bell" of the great Lake poet.

If this people was so old thirty-four hundred years ago, when was it young? We begin to believe, with Bailly,[2] in the existence of "ce peuple ancien qui nous a tout appris, excepté son nom et son existence."

It may, then, be interesting for us to glance at the state of science among these predecessors of ours. But let us remember that we are applying a severe test, when we compare their progress with the science of to-day. Let us remember that it is only within a hundred years that the return of comets has been predicted; that our knowledge of the constitution of the sun has been gained since 1859; that Newton has been dead only 147 years, and that Lagrange and La-

[1] "Book of Good Councils: written in Sanscrit, B. C. 1600;" translated by Edwin Arnold, M. A., Oxford, 1861.

[2] "This ancient people who have taught us every thing but their own name and their own existence."

place both lived and worked in our own century. When we consider what astronomy would be without these three great men—that is, what it *was* only so few years ago—we are better prepared to appreciate the studies which laid the remote foundations of their triumphs.

It would be impossible, within moderate limits, to determine the value of *Hindoo astronomy*, however interesting the effort might be, since we should enter at once into debateable ground, and come among great authorities in conflict.

Bailly, Delambre, Bentley, Davis, Hunter, Sir William Jones, and others, have various, often contradictory, beliefs to maintain. Some are partisans of the Greek, some of the Arab, others of the Hindoo scientists of long ago. But, fortunately, some of the original manuscript books of the Hindoos have come down to us: among others various complete treatises on mathematics, and these are authentic and of great age. Precisely of how great age it is difficult to ascertain. Bailly, a Hindoo partisan, accepts the largest estimate; Delambre, a detractor of Hindoo science, and an advocate of the Greek, believes the most important of them to have been written about A. D. 1114; while the translator of this manuscript, Colebrooke, a distinguished Sanscrit scholar, places the date of writing in A. D. 1150.

This treatise, the "Lílívatí" of Bháscara Achárya, is supposed to have been a compilation, and there are reasons for believing a portion of it to have been written about A. D. 628. However this may be, it is of the greatest interest, and its date is sufficiently remote to give to Hindoo mathematics a respectable antiquity.

The "Lílívatí," according to Delambre, was written to console the daughter of its author for her ill-success in obtaining a husband, and it speaks well for the Hindoo gentlewoman that such a means could be considered worth the attempting. It was called by her name, and many of the questions are addressed to her, as we shall see.

It opens most auspiciously with an invocation to Ganesa, as follows: "Having bowed to the Deity whose head is like an elephant's; whose feet are adored by gods; who, when called to mind, relieves his votaries from embarrassment, and bestows happiness upon his worshippers; I propound this easy process of computation, delightful by its elegance, perspicuous with words concise, soft, and correct, and pleasing to the learned."

Thus fairly launched, the author gives various tables of Hindoo moneys, weights, etc., and proceeds to business, not without another invocation, however, shorter this time: "Salutation to Ganesa, resplendent as a blue and spotless lotus; and delighting in the tremulous motion of the dark serpent, which is perpetually twining within his throat."

The principles of numeration and addition are then stated concisely, and he affably propounds his first question: "Dear, intelligent Lílívatí, if thou be skilled in addition and subtraction, tell me the sum of 2, 5, 32, 193, 18, 10, and 100, added together; and the remainder when their sum is subtracted from 10,000."

He then rapidly plunges into multiplication as follows: "Example. Beautiful and dear Lílívatí, whose eyes are like a fawn's! tell me what are the numbers resulting from 135 taken into 12? . . . . Tell me, auspicious woman, what is the quotient of the product divided by the same multiplier?"

The treatise continues rapidly through the usual rules, but pauses at the reduction of fractions to hold up the avaricious man to scorn: "The quarter of a sixteenth of the fifth of three-quarters of two-thirds of a moiety of a *dramma* was given to a beggar by a person from whom he asked alms; tell me how many cowry-shells the miser gave if thou be conversant in arithmetic with the reduction termed subdivision of fractions."

The "venerable preceptor," as Bháscara calls himself, illustrates what he terms the rule of supposition by the following example: "Out of a swarm of bees, one-fifth part settled on a blossom of *Cadamba;* and one-third on a flower of *Silind'hri;* three times the difference of those numbers flew to the bloom of a *Cutaja.* One bee which remained, hovered and flew about in the air, allured at the same moment by the pleasing fragrance of a jasmin and pandanus. Tell me, charming woman, the number of bees."

This example is sufficiently poetical, but there is given a section on interest, and one on purchase and sale for merchants. It is easily seen that this arithmetic varies but little from that taught in our common schools to-day. The processes are nearly the same, and the advance of the Hindoos in this science is due largely to their admirable system of notation, viz., that called the Arabic, which, however, was undoubtedly derived by the Arabs from Hindoo teachers, as is admitted by the best authorities.

The next section of the book is occupied with a kind of arithmetical geometry, which has for its basis the relation between the squares of the sides of a right-angled triangle. The demonstration of this celebrated theorem is given both geometrically and algebraically by one of the commentators. This algebraic demonstration is so short and so direct that it will be given: If C and D are the greater and less sides of a right-angled triangle, and B the hypothenuse whose greater and less segments are c and d, then—

$$B : C = C : c \quad \text{or} \quad c = \frac{C^2}{B}$$

Also, $$B : D = D : d \quad \text{or} \quad d = \frac{D^2}{B}$$

Therefore $B = c + d = \frac{C^2}{B} + \frac{D^2}{B}$ and $B^2 = C^2 + D^2$.

It is noteworthy that Wallis, in his "Treatise on Angular Sections," (Chapter VI.), gives this demonstration, and supposes it to be given for the first time.

The Hindoos, however, were not skilled in geometry. One of their authors even chides another for attempting to prove geometrically what can be seen by experience. One of the aphorisms of the present treatise is as follows: "That figure, though rectilinear, of which sides are proposed by some presumptuous person, wherein one side equals or exceeds the sum of the other sides, may be known to be no figure;" and the proof of this is thus given, "Let straight rods, of the length of the proposed sides, be placed on the ground, and the incongruity will be apparent."

The geometry of the circle in "Lílívatí" is the best feature of the book on plane figures. The "rule" of the text is that the ratio of the diameter to the circumference is $\frac{3927}{1250}$, or 3.1416 exactly.

This is given in the text without demonstration, but one of the commentators thus establishes it: the side of the inscribed hexagon is first found to be equal to the radius; the side of the dodecagon is derived from this; "from which, in like manner, may be found the side of a polygon with twenty-four sides; and so on, doubling the number of sides in the polygon until the side be near to the arc. The sum of such sides will be the circumference of the circle, nearly." The side of the polygon of three hundred and eighty-four sides is found, and the ratio given above is deduced.

The explanation of the method of finding the area of the circle is somewhat indirect, and is likewise ingenious. The circle is divided into two semicircles by a diameter: if this diameter is 14, the semi-circumference is equal to $21\frac{1239}{1250}$. Suppose a number of radii drawn, and the semi-circumference developed into a right line; each half of the circle will become a saw-shaped figure (Fig. 1); placing these to-

Fig. 1.

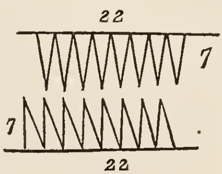
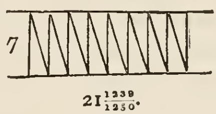


Fig. 2.



gether, we should have a rectangle, Fig. 2, of equal area with the circle. This, of course, leads to the formula, πr^2 *area circle* $= 2\pi r.\frac{r}{2} = \pi.r^2$.

To find the surface of the sphere, and its contents, similar methods are employed.

The following sections are concerned with some practical questions, as the determination of the number of boards which can be cut from a prism of wood, the number of measures of grain in a mound, and formulæ for the length of the shadows of gnomons. Sections on the subjects of permutations follow which are sufficiently obscure, and the treatise concludes with the neat sentiment that "joy and happiness is indeed ever increasing in this world for those who have Lílívatí clasped to their throats. . . ."

Next follows the "Vija-Ganita," a treatise on algebra, of which science the author observes: "Neither is algebra consisting in symbols, nor are the several sorts of it, analysis. Sagacity alone is the chief analysis: for vast is inference."

The methods of Hindoo algebra are rude. Positive quantities have no sign, while negative ones are distinguished by a dot. For the unknown quantities the different *colors* are used, and the initial letters of their names are placed in an equation. Equality must be expressed in words, for the sign was first used by Robert Recorde, who says, "No two things can be more equal than a pair of parallel lines."—(*Hutton.*)

Equations of the first and second degree are treated of, but with obscurity.

It is noteworthy that at least two references are made in this treatise to older authors, which deserve quotation as showing the nature of problems previously proposed.

"Example, by ancient authors. Five doves are to be had for three *drammas*; seven cranes for five; nine geese for seven; and three peacocks for nine: being a hundred of these birds for a hundred *drammas* for the prince's gratification."

"Example by an ancient author. What number multiplied by three and having one added to the product becomes a cube: and the cube root squared and multiplied by three and having one added, becomes a square?"

Enough has been given to show that the Hindoo mind was apt at mathematical logic, and to exhibit the characteristic grace of fancy with which it regarded science.

Arithmetic, when the world was young, was not inconsistent with fancy and with enjoyment. Algebra was regarded with a certain awe. We cannot better illustrate this than by one more quotation from the translation by Colebrooke of the "Vija-Ganita:"

"There is no end of instances, and therefore a few only are exhibited. Since the wide ocean of science is difficultly traversed by men of little understanding, and, on the other hand, the intelligent have no occasion for copious instruction, a particle of tuition conveys science to a comprehensive mind, and, having reached it, expands of its own impulse. . . . The rule-of-three terms constitute arithmetic; and sagacity, algebra."

THE STUDY OF SOCIOLOGY.

By HERBERT SPENCER.

XII.—*The Theological Bias.*

"WHAT a log for hell-fire!" exclaimed a Wahabee, on seeing a corpulent Hindoo. This illustration, startling by its strength of expression, which Mr. Gifford Palgrave gives[1] of the belief possessing these Mohammedan fanatics, prepares us for their general mode of thinking about God and man. Here is a sample of it:

"When 'Abd-el-Lateef, a Wahabee, was preaching one day to the people of Riad, he recounted the tradition according to which Mahomet declared that his followers should divide into seventy-three sects, and that seventy-two were destined to hell-fire, and one only to Paradise. 'And what, O messenger of God, are the signs of that happy sect to which is insured the exclusive possession of Paradise?' Whereto Mahomet had replied, 'It is those who shall be in all conformable to myself and to my companions.' 'And that," added 'Abd-el-Lateef, lowering his voice to the deep tone of conviction, 'that, by the mercy of God, are we, the people of Riad.'"[2]

For present purposes we are not so much concerned to observe the parallelism between this conception and the conceptions that have been, and are, current among sects of Christians, as to observe the effects produced by such conceptions on men's views of those who have alien beliefs, and on the views they are led to form of alien societies. What extreme misinterpretations of social facts result from the theological bias may be seen still better, in a case even more remarkable.

By Turner, by Erskine, and by the members of the United States Exploring Expedition, the characters of the Samoans are, as compared with the characters of the uncivilized generally, very favorably described. Though, in common with savages at large, they are said to be "indolent, covetous, fickle, and deceitful," yet they are also said to be "kind, good-humored, . . . desirous of pleasing, and very hospitable. Both sexes show great regard and love for their children;" and age is much respected. "A man cannot bear to be called stingy or disobliging." The women "are remarkably domestic and virtuous." Infanticide after birth is unknown in Samoa. "The treatment of the sick was . . . invariably humane and all that could be expected." Observe, next, what is said of their cannibal neighbors, the Fijians. They are indifferent to human life; they live in perpetual dread of one another; and, according to Jackson, treachery is considered by them an accomplishment. "Shedding of blood is to him" (the Fijian) "no

[1] "Journey through Central and Eastern Arabia," vol. ii., p. 370.

[2] Ibid., vol. ii., p. 22.

crime, but a glory." They kill the decrepit, maimed, and sick. While, on the one hand, infanticide covers nearer two-thirds than one-half of the births, on the other hand, "one of the first lessons taught the infant is, to strike its mother:" anger and revenge are fostered. Inferiors are killed for neglecting proper salutes; slaves are buried alive with the posts on which a king's house stands; and ten or more men are slaughtered on the decks of a newly-launched canoe, to baptize it with their blood. A chief's wives, courtiers, and aides-de-camp, are strangled at his death—being thereby honored. Cannibalism is so rampant that a chief, praising his deceased son, wound up his eulogy by saying that he would "kill his own wives if they offended him, and eat them afterward." Victims were sometimes roasted alive before being eaten; and Tanoa, one of their chiefs, cut off a cousin's arm, drank the blood, cooked the arm and ate it in presence of the owner, who was then cut to pieces. Their gods, described as having like characters, commit like acts. They eat the souls of those who are devoured by men, having first "roasted" them (the "souls" being simply material duplicates). The Fiji gods "are proud and revengeful, and make war, and kill and eat each other;" and among their names are "the adulterer," "the woman-stealer," "the brain-eater," "the murderer." Such being the account of the Samoans, and such the account of the Fijians, let us ask what the Fijians think of the Samoans. "The Feegeeans looked upon the Samoans with horror, because they had no religion, no belief in any such deities" (as the Feegeean), "nor any of the sanguinary rites which prevailed in other islands" [1]—a fact quite in harmony with that narrated by Jackson, who, having behaved disrespectfully to one of their gods, was angrily called by them "the white infidel."

Any one may read, while running, the lesson conveyed; and, without stopping to consider much, may see its application to the beliefs and sentiments of civilized races. The ferocious Fijian doubtless thinks that, to devour a human victim in the name of one of his cannibal gods, is a meritorious act; while he thinks that his Samoan neighbor, who makes no sacrifices to these cannibal gods, but is just and kind to his fellows, thereby shows that meanness goes along with his shocking irreligion. Construing the facts in this way, the Fijian can form no rational conception of Samoan society. With vices and virtues interchanged in conformity with his creed, the benefits of certain social arrangements, if he thinks about them at all, must seem evils and the evils benefits.

Speaking generally, then, each system of dogmatic theology, with the sentiments that gather round it, becomes an impediment in the way of Social Science. The sympathies drawn out toward one creed and the correlative antipathies aroused by other creeds, distort the interpretations of all the associated facts. On these institutions and

[1] Lubbock's "Prehistoric Times," second edition, p. 442.

their results the eyes are turned with a readiness to observe every thing that is good, and on those with a readiness to observe every thing that is bad. Let us glance at some of the consequent perversions of opinion.

Already we have seen by implication that the theological element of a creed, subordinating the ethical element as it does completely in early stages of civilization and very considerably in later stages, maintains a standard of right and wrong, relatively good perhaps, but perhaps absolutely bad—good, that is, as measured by the requirements of the place and time, bad as measured by the requirements of an ideal society. And, sanctifying, as an associated theology may thus do, false conceptions of right and wrong, it falsifies the measures by which the effects of institutions are to be estimated. Obviously the sociological conclusions must be vitiated if beneficial and detrimental effects are not respectively recognized as such. An illustration enforcing this is worth giving. Here is Mr. Palgrave's account of Wahabee morality, as disclosed in answers to his questions:

"'The first of the great sins is the giving divine honors to a creature.'

"'Of course,' I replied, 'the enormity of such a sin is beyond all doubt. But if this be the first, there must be a second; what is it?'

"'Drinking the shameful,' in English, 'smoking tobacco,' was the unhesitating answer.

"'And murder, and adultery, and false witness?' I suggested.

"'God is merciful and forgiving,' rejoined my friend; 'that is, these are merely little sins.'

"'Hence two sins alone are great, polytheism and smoking,' I continued, though hardly able to keep countenance any longer. And 'Abd-el-Kareem, with the most serious asseveration, replied that such was really the case."[1]

Clearly a creed which makes smoking one of the blackest crimes, and has only mild reprobation for the worst acts committed by man against man, negatives any thing like Social Science. Habits and institutions not being judged by the degrees in which they conduce to social welfare, the ideas of better and worse, as applying to social arrangements, cannot exist; and such notions as progress and retrogression are excluded. But that which holds so conspicuously in this case holds more or less in all cases. At the present time, as in past times, and in our own society as in other societies, public acts are judged by two tests—the test of supposed divine approbation, and the test of conduciveness to human welfare. Though, as civilization advances, there grows up the belief that the second test is equivalent to the first, though, consequently, conduciveness to human welfare comes to be more directly considered, yet the test of supposed divine approbation, as inferred from the particular creed believed, continues to be very generally used. The wrongness of conduct is conceived as con-

[1] "Journey through Central and Eastern Arabia," vol. ii., p. 11.

sisting in the implied disobedience to the supposed commands, and not as consisting in its intrinsic character as causing suffering to others or to self. Inevitably the effect on sociological thinking is, that institutions and actions are judged more by their apparent congruity or incongruity with the established cult than by their tendencies to further or to hinder well-being.

This effect of the theological bias, manifest enough everywhere, has been forced on my attention, by one whose mental attitude often supplies me with matter for speculation—an old gentleman who unites the religion of amity and the religion of enmity in startling contrast. On the one hand, getting up early to his devotions, going to church even at great risk to his feeble health, always staying for the sacrament when there is one, he displays what is ordinarily regarded as an exemplary piety. On the other hand, his thoughts ever tend in the direction of warfare: fights on sea and land furnish topics of undying interest to him; he revels in narratives of destruction; his talk is of cannon. To say that he divides his reading between the Bible and Alison, or some kindred book, is an exaggeration; but still it serves to convey an idea of his state of feeling. Now you may hear him waxing wroth over the disestablishment of the Irish Church, which he looks upon as an act of sacrilege; and now, when the conversation turns on works of art, he names, as engravings which above all others he admires, Cœur-de-Lion fighting Saladin, and Wellington at Waterloo. Or, after manifesting some kindly feeling, which, to give him his due, he frequently does, he will shortly pass to some bloody encounter, the narration of which makes his voice tremulous with delight. Marvelling though I did at first over these incongruities of sentiment and belief, the explanation was reached on observing that the subordination-element of his creed was far more dominant in his consciousness than the moral element. Watching the movements of his mind made it clear that, to his imagination, God was symbolized as a kind of transcendently powerful sea-captain, and made it clear that he went to church from a feeling akin to that with which, as a middy, he went to muster. On perceiving that this, which is the sentiment common to all religions, whatever be the name or ascribed nature of the deity worshipped, was supreme in him, it ceased to be inexplicable that the sentiment to which the Christian religion specially appeals should be so readily overridden. It became easier to understand how, when the Hyde-Park riots took place, he could wish that we had Louis Napoleon over here to shoot down the mob, and how he could recall, with more or less of chuckling, the deeds of press-gangs in his early days.

That the theological bias, thus producing conformity to moral principles from motives of obedience only, and not habitually insisting on such principles because of their intrinsic value, obscures sociological truths, will now not be difficult to see. The tendency is to substitute formal recognitions of such principles for real recognitions. So long as they are not contravened directly enough to suggest disobedience, they may be readily contravened indirectly; for the reason that there has not been cultivated the habit of contemplating consequences as they work out in remote ways. Hence it happens that social arrangements essentially at variance with the ethics of the creed give no offence to those who are profoundly offended by whatever seems at variance with its theology. Maintenance of the dogmas and forms of the religion becomes the primary, all-essential thing; and the secondary thing, often sacrificed, is the securing of those relations among men which the spirit of the religion requires. How conceptions of good and bad in social affairs are thus warped, the pending controversy about the Athanasian creed shows us. Here we have theologians who believe that our national welfare will be endangered, if there is not in all churches an enforced repetition of the dogmas that Father, Son, and Holy Ghost, are each of them Almighty; that yet there are not three Almighties, but one Almighty; that one of the Almighties suffered on the cross and descended into hell to pacify another of them; and that, whoever does not believe this, "without doubt shall perish everlastingly." They say that, if the State makes its priests threaten with eternal torments all who doubt these doctrines, things will go well; but, if those priests, who, in this threat, perceive the devil-worship of the savage usurping the name of Christianity, are allowed to pass it by in silence, woe to the nation! Evidently the theological bias leading to such a conviction entirely excludes Sociology, considered as a science.

Under its special forms, as well as under its general form, the theological bias brings errors into the estimates men make of societies and institutions. Sectarian antipathies, growing out of differences of doctrine, disable the members of each religious community from fairly judging other religious communities. It is always difficult, and often impossible, for the zealot to conceive that his own religious system and his own zeal on its behalf may have but a relative truth and a relative value; or to conceive that there may be relative truths and relative values in alien beliefs and the fanaticisms which maintain them. Though the adherent of each creed has continually thrust on his attention the fact that adherents of other creeds are no less confident than he is—though he can scarcely fail sometimes to reflect that these adherents of other creeds have, in nearly all cases, simply accepted the dogmas current in the places and families they were born in, and that he has done the like—yet the special theological bias which his education and surroundings have given him, makes it almost beyond imagination that these other creeds may, some of them, have justifications as good as, if not better than, his own, and that the rest, along with certain amounts of absolute worth, may have their special fitnesses to the people holding them.

We cannot doubt, for instance, that the feeling with which Mr. Whalley or Mr. Newdegate regards Roman Catholicism must cause extreme reluctance to admit the services which Roman Catholicism rendered to European civilization in the past; and must make almost impossible a patient hearing of any one who thinks that it renders some services now. Whether great benefit did not arise in early times from the tendency toward unification produced within each congeries of small societies by a common creed authoritatively imposed?—whether papal power, supposed to be divinely deputed, and therefore tending to subordinate the political authorities during turbulent feudal ages, did not serve to curb warfare and further civilization?—whether the strong tendency shown by early Christianity to lapse into separate local paganisms, was not beneficially checked by an ecclesiastical system having a single head supposed to be infallible?—whether morals were not improved, manners softened, slavery ameliorated, and the condition of women raised, by the influence of the Church, notwithstanding all its superstitions and bigotries?—are questions to which Dr. Cumming, or other vehement opponent of popery, could not bring a mind open to conviction. Similarly, it is beyond the power of the Roman Catholic to see the meaning of Protestantism, and recognize its value. To the Ultramontane, holding that the temporal welfare no less than the eternal salvation of men depends on submission to the Church, it is incredible that Church-authority has but a transitory value, and that the denials of authority which have come along with accumulation of knowledge and change of sentiment, mark steps from a lower social *régime* to a higher. Naturally, to the sincere Papist, schism is a crime, and books that throw doubt on the established beliefs are accursed. Nor need we wonder when from such a one there comes a saying like that of the Mayor of Bordeaux, so much applauded by the Comte de Chambord, that "the Devil was the first Protestant;" or when, along with this, there goes a vilification of Protestants too repulsive to be repeated. Clearly, with such a theological bias, fostering such ideas respecting Protestant morality, there must be extremely false estimates of Protestant institutions, and of all the institutions going along with them.

In less striking ways, but still in ways sufficiently marked, the special theological bias warps the judgments of Conformists and Nonconformists among ourselves. A fair estimate of the advantages which our State-Church has yielded is not to be expected from the zealous dissenter: he sees only the disadvantages. Whether voluntaryism could have done centuries ago all that it can do now?—whether a State-supported Protestantism was not once the best thing practicable?—are questions which he is unlikely to discuss without prejudice. Contrariwise, the churchman is reluctant to believe that the union of Church and State is beneficial only during a certain phase of progress. He knows that within the Establishment divisions are daily increasing, while voluntary agency is daily doing a larger share of the work originally undertaken by the State; but he does not join this with the fact that outside the Establishment the power of Dissent is growing: he resists the inference that these changes are parts of a general change by which the political and religious agencies, which have been differentiating from the beginning, are being separated and specialized. He is averse to the conception that just as Protestantism at large was a rebellion against an Ecclesiasticism which dominated over Europe, so Dissent among ourselves is a rebellion against an Ecclesiasticism which dominates over England; and that the two are but successive stages of the same beneficial development. That is to say, his bias prevents him from contemplating the facts in a way favorable to scientific interpretations of them.

Everywhere, indeed, the special theological bias accompanying a special set of doctrines inevitably prejudges many sociological questions. One who holds a creed as absolutely true, and who by implication holds the multitudinous other creeds to be absolutely false in so far as they differ from his own, cannot entertain the supposition that the value of a creed is relative. That a particular religious system is, in a general sense, a natural part of the particular society in which it is found, is an entirely alien conception; and, indeed, a repugnant one. The dogmatic theology which he holds unquestionably true, he thinks good for all places and all times. He does not doubt that, when transplanted to a horde of savages, it will be duly understood by them, duly appreciated by them, and work on them results such as those he experiences from it. Thus prepossessed, he passes over the proofs which recur everywhere, that a people is no more capable of suddenly receiving a higher form of religion than it is capable of suddenly receiving a higher form of government; and that inevitably with such religion, as with such government, there will go on a degradation that presently reduces it to one differing but nominally from that which previously existed. In other words, his special theological bias blinds him to an important class of sociological truths.

The effects of the theological bias need no further elucidation. We will turn our attention to the distortions of judgment caused by the anti-theological bias. Not only the actions of religious dogmas, but also the reactions against them, are disturbing influences we have to beware of. Let us glance first at an instance of that indignation against the established creed, which all display more or less when they emancipate themselves from it.

"A Nepaul king, Rum Bahadur, whose beautiful queen, finding that her lovely face had been disfigured by small-pox, poisoned herself, 'cursed his kingdom, her doctors, and the gods of Nepaul, vowing vengeance on all.' Having ordered the doctors to be flogged, and the right ears and nose of each to be cut off, 'he then wreaked his vengeance on the gods of Nepaul, and, after abusing them in the most gross way, he accused them of having obtained from him twelve thousand goats, some hundred-weight of sweetmeats, two thousand gallons of milk, etc., under false pretences.' . . . He then ordered all the artillery, varying from three- to twelve-pounders, to be brought in front of the palace. . . . All the guns were then loaded to the muzzle, and down he marched to the headquarters of the Nepaul deities. . . . All the guns were drawn up in front of the several deities, honoring the most sacred with the heaviest metal. When the order to fire was given, many of the chiefs and soldiers ran away panic-stricken, and others hesitated to obey the sacrilegious order; and not until several gunners had been cut down, were the guns opened. Down came the gods and goddesses from their hitherto sacred positions; and, after six hours' heavy cannonading, not a vestige of the deities remained."[1]

This, which is one of the most remarkable pieces of iconoclasm on record, exhibits in an extreme form the reactive antagonism usually accompanying abandonment of an old belief—an antagonism that is high in proportion as the previous submission has been profound. By stabling their horses in cathedrals and treating the sacred places and symbols with intentional insult, the Puritans displayed this feeling in a marked manner; as again did the French revolutionists by pulling down sacristies and altar-tables, tearing mass-books into cartridge-papers, drinking brandy out of chalices, eating mackerel off patenas, making mock ecclesiastical processions, and holding drunken revels in churches. Though in our day the breaking of bonds less rigid, effected by struggles less violent, is followed by a less excessive opposition and hatred, yet habitually the throwing-off of the old form implies a replacing of the previous sympathy by more or less of antipathy: perversion of judgment caused by the antipathy taking the place of that caused by the sympathy. What before was reverenced as wholly true is now scorned as wholly false; and what was regarded as invaluable is now rejected as of no value at all.

In some, this state of sentiment and belief continues. In others, the reaction is in course of time followed by a re-reaction. To carry out the Carlylean figure, the old clothes that had been outgrown and were finally torn off and thrown aside with contempt, come presently to be looked back upon with more calmness and with the recognition that they did good service in their time—nay, perhaps with the doubt whether they were not thrown off too soon. This re-reaction may be feeble or may be strong; but only when it takes place in due amount is there a possibility of balanced judgments either on religious questions or on those questions of Social Science into which the religious element enters.

Here we have to glance at the sociological errors into which the anti-theological bias betrays those in whom it does not become qualified. Thinking only of what is erroneous in the rejected creed, they ignore the truth for which it stands; contemplating only its mischiefs,

[1] "Five Years' Residence in Nepaul," by Captain Thomas Smith, vol. i., p. 168.

they overlook its benefits; and, doing this, they think that nothing but good would result from its general abandonment. Let us observe the tacit assumptions made in drawing this conclusion.

It is assumed, in the first place, that adequate guidance for conduct in life, private and public, could be had; and that a moral code, rationally elaborated by men as they now are, would be duly operative upon them. Neither of these propositions commends itself when we come to examine the evidence. We have but to observe human action as it meets us at every turn, to see that the average intelligence, incapable of guiding conduct even in simple matters, where but a very moderate reach of reason would suffice, must fail in apprehending with due clearness the natural sanctions of ethical principles. The unthinking ineptitude with which even the routine of life is carried on by the mass of men, shows clearly that they have nothing like the insight required for self-guidance in the absence of an authoritative code of conduct. Take a day's experience, and observe the lack of thought indicated from hour to hour.

You rise in the morning, and, while dressing, take up a phial containing a tonic, of which a little has been prescribed for you; but, after the first few drops have been counted, succeeding drops run down the side of the phial—all because the lip is shaped without regard to the requirement. Yet millions of such phials are annually made by glass-makers, and sent out by thousands of druggists: so small being the amount of sense brought to bear on business. Now, turning to the looking-glass, you find that, if not of the best make, it fails to preserve the attitude in which you put it; or, if what is called a "box" looking-glass, you see that the maintenance of its position is insured by an expensive appliance that would have been superfluous had a little reason been used. Were the adjustment such that the centre of gravity of the glass came in the line joining the points of support (which would be quite as easy an adjustment), the glass would remain steady in whatever attitude you gave it. Yet year after year tens of thousands of looking-glasses are made without regard to so simple a need. Presently you go down to breakfast, and, taking some Harvey or other sauce with your fish, find the bottle has a defect like that which you found in the phial: it is sticky from the drops which trickle down, and occasionally stain the table-cloth. Here are other groups of traders, similarly so economical of thought that they do nothing to rectify this obvious inconvenience. Having breakfasted, you take up the paper, and, before sitting down, wish to put some coal on the fire. But the lump you seize with the tongs slips out of them, and, if large, you make several attempts before you succeed in lifting it—all because the ends of the tongs are smooth. Makers and venders of fire-irons go on, generation after generation, without meeting this evil by the simple remedy of giving to these smooth ends some projecting points, or even roughening them by a few burrs with a chisel. Having at length grasped the lump and put it on the fire, you begin to read; but, before you have got through the first column, you are reminded, by the changes of position which your sensations prompt, that men still fail to make easy-chairs. And yet the guiding principle is simple enough. Just that advantage secured by using a soft seat in place of a hard one—the advantage, namely, of spreading over a larger area the pressure of the weight to be borne, and so making the pressure less intense at any one point—is an advantage to be sought in the *form* of the chair. Ease is to be gained by making the shapes and relative inclinations of seat and back such as will evenly distribute the weight of the trunk and limbs over the widest possible supporting surface, and with the least straining of the parts out of their natural attitudes. And yet only now, after these thousands of years of civilization, are there being reached (and that not rationally but empirically) approximations to the structure required.

Such are the experiences of the first hour; and so they continue all the day through. If you watch and criticise, you may see that the immense majority bring to bear, even on those actions which it is the business of their lives to carry on effectually, an extremely small amount of faculty. Get a workman to do something for you that is more or less new, and not the clearest explanations and sketches will prevent him from blundering; and, to any expression of surprise, he will reply that he was not brought up to it: scarcely ever betraying the slightest shame in confessing that he cannot do a thing he was not taught to do. Similarly throughout the higher grades of activity. Remember how generally improvements in manufactures come from outsiders, and you are at once shown with what mere unintelligent routine manufactures are commonly carried on. Examine into the management of mercantile concerns, and you perceive that those engaged in them mostly do nothing more than move in the ruts that have gradually been made for them by the process of trial and error during a long succession of generations. Indeed, it almost seems as though most men made it their aim to get through life with the least possible expenditure of thought.

How, then, can there be looked for such power of self-guidance as, in the absence of inherited authoritative rules, would require them to understand why, in the nature of things, these modes of action are injurious and those modes beneficial—would require them to pass beyond proximate results, and see clearly the involved remote results as worked out on self, on others, and on society?

The incapacity need not, indeed, be inferred; it may be seen, if we do but take an action concerning which the sanctified code is silent. Listen to a conversation about gambling; and, where reprobation is expressed, note the grounds of the reprobation. That it tends toward the ruin of the gambler; that it risks the welfare of family and friends;

that it alienates from business, and leads into bad company—these, and such as these, are the reasons given for condemning the practice. Rarely is there any recognition of the fundamental reason. Rarely is gambling condemned because it is a kind of action by which pleasure is obtained at the cost of pain to another. The normal obtainment of gratification, or of the money which purchases it, implies, in the first place, that there has been put forth equivalent effort of a kind which, in some way, furthers the general good; and implies, in the second place, that those from whom the money is received, get, directly or indirectly, equivalent satisfactions. But in gambling the opposite happens. Benefit received does not imply effort put forth; and the happiness of the winner involves the misery of the loser. This kind of action is therefore essentially anti-social—sears the sympathies, cultivates a hard egoism, and so produces a general deterioration of character and conduct.

Clearly, then, a visionary hope misleads those who think that in an imagined age of reason, which might forthwith replace an age of beliefs but partly rational, conduct would be correctly guided by a code directly based on considerations of utility. A utilitarian system of ethics cannot at present be correctly thought out even by the select few, and is quite beyond the mental reach of the many. The value of the inherited and theologically-enforced code is that it formulates, with some approach to correctness, the accumulated results of past human experience. It has not arisen rationally but empirically. During all past times mankind have eventually gone right after trying all possible ways of going wrong. The wrong-goings have been habitually checked by disaster, and pain, and death; and the right-goings have been continued because not thus checked. There has been a growth of beliefs corresponding to these good and evil results. Hence the code of conduct, embodying discoveries slowly and almost unconsciously made through a long series of generations, has transcendent authority on its side.

Nor is this all. Were it possible forthwith to replace a traditionally-established and supernaturally-warranted system of rules by a system of rules rationally elaborated, no such rationally-elaborated system of rules would be adequately operative. To think that it would implies the thought that men's beliefs and actions are throughout determined by intellect; whereas they are in much larger degrees determined by feeling.

There is a wide difference between the formal assent men give to a proposition they cannot gainsay, and the efficient belief which produces active conformity to it. Often the most conclusive argument fails to produce a conviction capable of swaying conduct; and often mere assertion, with great emphasis and signs of confidence on the part of the utterer, will produce efficient conviction where there is no evidence, and even in spite of adverse evidence. Especially is this so among those of little culture. Not only may we see that strength of affirmation and an authoritative manner create faith in them, but we may see that their faith sometimes actually decreases if explanation is given. The natural language of belief in another is that which generates their belief—not the logically-conclusive evidence. The dependencies of this they cannot clearly follow; and, in trying to follow it, they so far lose themselves that premisses and conclusion, not perceived to stand in necessary relation, are rendered less coherent than by putting them in juxtaposition and strengthening their connection by a wave of the emotion which emphatic affirmation raises.

Nay, it is even true that the most cultivated intelligences, capable of criticising evidence and valuing arguments to a nicety, are not thereby made rational to the extent that they are guided by intellect apart from emotion. Continually men of the widest knowledge deliberately do things they know to be injurious; suffer the evils that transgression brings; are deterred a while by the vivid remembrance of them; and, when the remembrance has become faint, transgress again. Often the emotional consciousness overrides the intellectual consciousness absolutely, as hypochondriacal patients show us. A sufferer from depressed spirits may have the testimony of his physicians, verified by numerous past experiences of his own, showing that his gloomy anticipations are illusions caused by his bodily state; and yet the conclusive proofs that they are irrational do not enable him to get rid of them; he continues to feel sure that disasters are coming on him.

All which, and many kindred facts, make it certain that the operativeness of a moral code depends much more upon the emotions called forth by its injunctions than on the consciousness of the utility of obeying such injunctions. The feelings excited during early life toward moral principles, by witnessing the social sanction and the religious sanction they possess, influence conduct far more than the perception that conformity to such principles conduces to welfare. And, in the absence of the feelings which manifestations of these sanctions arouse, the utilitarian belief alone would be inadequate to produce conformity.

It is true that the sentiments in the higher races, and especially in superior members of the higher races, are now in considerable degrees adjusted to these principles; the sympathies that have become organic in the most developed men produce some spontaneous conformity to altruistic precepts. Even to such, however, the social sanction, which is in part derived from the religious sanction, is important as strengthening the influence of such precepts. And, to those endowed with less of moral sentiment, these sanctions are still more important aids to guidance.

Thus the anti-theological bias leads to serious error, both when it ignores the essential share hitherto taken by religious systems in giving force to certain principles of action, in part absolutely good and in part good relatively to the needs of the time, and again when it prompts the notion that now these principles might be so established on rational bases as to rule men effectually through their enlightened intellects.

These errors, however, which the anti-theological bias produces, are superficial compared with the error that remains. The antagonism to superstitious beliefs habitually leads to entire rejection of them. They are thrown aside with the assumption that, along with so much that is wrong, there is nothing right. Whereas the truth, recognizable only after antagonism has spent itself, is, that the wrong beliefs rejected are superficial, and that a right belief hidden by them remains when they have been rejected. Those who defend, equally with those who assail, religious creeds, suppose that every thing turns on the maintenance of the particular dogmas at issue; whereas the dogmas are but temporary forms of that which is permanent.

The process of Evolution which has progressively modified and advanced men's conceptions of the Universe, will continue to modify and advance them during the future. The ideas of Cause and Origin, which have been gradually changing, will change still further. But no changes in them, even when pushed to the extreme, will expel them from consciousness; and there can, therefore, never be an extinction of the correlative sentiments. No more in this than in other things will Evolution alter its general direction: it will continue along the same lines as hitherto. And, if we wish to see whither it tends, we have but to observe how there has been thus far a decreasing concreteness of the consciousness to which the religious sentiment is related, to infer that hereafter this concreteness will further diminish: leaving behind a substance of consciousness for which there is no adequate form, but which is none the less persistent and powerful.

Without seeming so, the development of religious sentiment has been continuous from the beginning; and its nature when a germ was the same as is its nature when fully developed. The savage first shows it in the feeling excited by some display of power in another exceeding his own power—some skill, some sagacity, in his chief, leading to a result he does not understand—something which has the element of mystery and arouses his wonder. To his unspeculative intellect there is nothing wonderful in the ordinary course of things around. The regular sequences, the constant relations, do not present themselves to him as problems needing interpretation. Only anomalies in that course of causation which he knows most intimately, namely, human will and power, excite his surprise and raise questions. And only when experiences of other classes of phenomena become multiplied enough for generalization, does the occurrence of anomalies among these also, arouse the same idea of mystery and the same sentiment of wonder:

hence one kind of fetiehism. Passing over all intermediate stages, the truth to be noted is, that as fast as explanation of the anomalies dissipates the wonder they excited, there grows up a wonder at the uniformities—there arises the question how eome they to be uniformities? As fast as Seience transfers more and more things from the eategory of irregularities to the eategory of regularities, the mystery that once attaehed to the superstitious explanations of them beeomes a mystery that attaehes to the seientific explanations of them: there is a merging of many speeial mysteries in one general mystery. The astronomer, having shown that the motions of the Solar System imply a uniform and invariably-acting foree he calls gravitation, finds himself absolutely ineapable of coneeiving the force. Though he helps himself to think of the Sun's action on the Earth by assuming an intervening medium, and finds he *must* do this if he thinks about it at all; yet the mystery reappears when he asks what is the constitution of this medium. Though eompelled to use units of ether as symbols, he sees that they ean be but symbols. Similarly with the physieist and the chemist. Though the hypothesis of atoms and moleeules enables them to work out multitudinous interpretations that are verified by experiment, yet the ultimate unit of matter admits of no eonsistent eoneeption. Instead of the particular mysteries presented by those aetions of matter they have explained, there rises into prominenee the mystery whieh matter universally presents, and whieh proves to be absolute. So that, beginning with the germinal idea of mystery whieh the savage gets from a display of power in another transeending his own, and the germinal sentiment of awe aeeompanying it, the progress is toward an ultimate recognition of a mystery behind every aet and appearance, and a transfer of the awe from something speeial and oceasional to something universal and unceasing.

No one need expect, then, that the religious consciousness will die away, or will change the lines of its evolution. Its specialties of form, onee strongly marked and beeoming less distinct during past mental progress, will eontinue to fade; but the substanee of the eonsciousness will persist. That the objeet-matter ean be replaeed by another object-matter, as supposed by those who think the "Religion of Humanity" will be the religion of the future, is a belief eountenanced neither by induction nor by deduetion. However dominant may beeome the moral sentiment enlisted on behalf of Humanity, it ean never exclude the sentiment, alone properly called religious, awakened by that whieh is behind Humanity and behind all other things. The ehild, by wrapping its head in the bedelothes, may for a moment get rid of the distinet consciousness of surrounding darkness; but the eonseiousness, though rendered less vivid, survives, and imagination persists in oecupying itself with that whieh lies beyond perception. No sueh thing as a "Religion of Humanity" ean ever do more than temporarily shut out the thought of a Power of which Humanity is but a small and fugitive product—which was in course of ever-changing manifestation before Humanity was, and will continue through other manifestations when Humanity has ceased to be.

To recognitions of this order the anti-theological bias is a hindrance. Ignoring the truth for which religions stand, it undervalues religious institutions in the past, thinks they are needless in the present, and expects they will leave no representatives in the future. Hence many errors in sociological reasonings.

To the various other forms of bias, then, against which we must guard in studying the Social Science, has to be added the bias, perhaps as powerful and perverting as any, which religious beliefs and sentiments produce. This, both generally under the form of theological bigotry, and specially under the form of sectarian bigotry, affects the judgments about public affairs; and reactions against it give the judgment an opposite warp.

The theological bias, under its general form, tending to maintain a dominance of the subordination-element of religion over its ethical element—tending, therefore, to measure actions by their formal congruity with a creed rather than by their intrinsic congruity with human welfare—is unfavorable to that estimation of worth in social arrangements which is made by tracing out results. And, while the general theological bias brings into Sociology an element of distortion, by using a kind of measure foreign to the science properly so called, the special theological bias brings in further distortions, arising from the special measures of this kind which it uses. Institutions, old and new, home and foreign, are considered as congruous or incongruous with a particular set of dogmas, and liked or disliked accordingly: the obvious result being that, since the sets of dogmas differ in all times and places, the sociological judgments affected by them must inevitably be wrong in all cases but one, and probably in all cases.

On the other hand, the reactive bias distorts conceptions of sociological phenomena by undervaluing religious systems. It generates an unwillingness to see that a religious system is a normal and essential factor in every evolving society; that the specialties of it have certain fitnesses to the social conditions; and that, while its forms are temporary, its substance is permanent. In so far as the anti-theological bias causes an ignoring of these truths, or an inadequate appreciation of them, it causes misinterpretations.

To maintain the required equilibrium, amid the conflicting sympathies and antipathies which contemplation of religious beliefs inevitably generates, is difficult. In presence of the theological thaw going on so fast on all sides, there is on the part of many a fear, and on the part of some a hope, that nothing will remain. But the hopes and the fears are alike groundless; and must be dissipated before balanced judgments in Social Science can be formed. Like the transformations that have succeeded one another hitherto, the transformation now in progress is but an advance from a lower form, no longer fit, to a higher and fitter form; and neither will this transformation, nor kindred transformations to come hereafter, destroy that which is transformed any more than past transformations have destroyed it.

VENUS ON THE SUN'S FACE.

By R. A. PROCTOR, B. A.,
AUTHOR OF "OTHER WORLDS THAN OURS," ETC.

EACH evening during the month of April the planet of Love could be seen in the west for a few hours after sunset. She set earlier and earlier each successive night—overtaking the sun, as it were—and toward the end of April she could no longer be detected. On the 5th of May she had overtaken the sun, passing him at a distance of about three times his own breadth above or to the north of his disk. When these lines appear she will be a morning star. This passage by the sun is the last made by Venus (at least when on the hither side of him) before the long-desired and now famous transit of December 9, 1874, when, instead of passing *by* the sun, either above or below his disk, as she usually does, she will pass right across his face.

So much has been said of late respecting this approaching phenomenon, and so much importance is deservedly attached to it, that my readers will probably be interested by a brief and simple account of the matter. In particular, some may desire to know what has been the special aim of the controversy recently and still in progress. Before entering on these matters, I shall make a few remarks on the history of former transits.

The first occasion on which Venus was ever seen on the sun's face was on November 24, 1639 (Old Style), corresponding to December 4th (New Style). It is rather singular that then, somewhat as at present, doubts had arisen, owing to a difference of opinion between an astronomer of established reputation and one less known to the scientific world. The Belgian astronomer Lansberg had stated in his "Tables of the Motion of Venus" that no transit would occur in 1639. Young Horrox, while preparing himself for practical observation, undertook (apparently from sheer love of science) the computation of Venus's motions from the tables of Lansberg. These tables were so highly valued by their author that he had spoken of them as superior to all others—"quantum lenta solent inter viburna cupressi." But Horrox recognized many imperfections in them, and at length, as he says, "broke off the useless computation, resolved for the future with my own eyes to observe the positions of the stars in the heavens; but, lest so many hours should be entirely thrown away," he made use of his results to predict the positions of the planets. "While thus engaged, I received," he proceeds, "my first intimation of the remarkable conjunction of Venus and the sun; and I regard it as a very fortunate occurrence, insomuch as about the beginning of October it induced me, in expectation of so grand a spectacle, to observe with increased attention." Nevertheless, his heart was wroth within him against Lansberg, insomuch that he could not refrain from the extreme step of "forgiving" him in the following agreeable terms: "I pardon, in the mean time, the miserable arrogance of the Belgian astronomer who has overloaded his useless tables with such unmerited praise, and cease to lament the misapplication of my own time, deeming it a sufficient reward that I was thereby led to consider and foresee the appearance of Venus in the sun. But, on the other hand, may Lansberg forgive me" (this is exquisite) "that I hesitated to trust him in an observation of such importance, and from having been so often deceived by his pretensions to universal accuracy that I disregarded the general reception of his tables. . . . Lest a vain exultation should deceive me," he proceeds, "and to prevent the chance of disappointment, I not only determined diligently to watch the important spectacle myself, but exhorted others whom I knew to be fond of astronomy to follow my example; in order that the testimony of several persons, if it should so happen, might the more effectually promote the attainment of truth, and because by observing in different places our purpose would be less likely to be defeated by the accidental interposition of clouds, or any fortuitous impediment." He was particularly anxious because Jupiter and Mercury seemed by their positions to threaten bad weather. "For," says he, "in such apprehension I coincide with the opinion of the astrologers, because it is confirmed by experience; but in other respects I cannot help despising their puerile vanities." Among the astronomers to whom he wrote was his friend Crabtree.[1]

Horrox calculated that the transit would begin at three o'clock in the afternoon of November 24th; but "being unwilling to depend entirely on his own opinion," he began his watch on Saturday, November 23d. On Sunday morning he resumed it, only interrupting it to go to church—so, at least, I interpret his remark that he "was called away by business of the highest importance, which, for these ornamental pursuits," he "could not with propriety neglect. . . . About fifteen

[1] Both these ardent students of astronomy died young. Horrox (or Horrocks, as his name is now more commonly spelled) was but twenty years old when he calculated the transit, so that his feat may not inaptly be compared to that of Adams in calculating the place of the unknown planet Neptune within a few months of taking his degree. Each instance of an early mastery of difficult problems was fated to meet with neglect; but Horrox died before justice had been done him. Adams was quickly able to prove that his work was sound, notwithstanding the coolness with which it had been received by the Astronomer Royal. Horrocks died in 1641, in his twenty-second year. Crabtree is supposed to have been killed at the battle of Naseby Field.

minutes past three," he proceeds, "when I was again at liberty to continue my labors, the clouds, as if by divine interposition, were entirely dispersed, and I was once more invited to the grateful task of repeating my observations. I then beheld a most agreeable spectacle, the object of my sanguine wishes, a spot of unusual magnitude and of a perfectly circular shape, which had already fully entered upon the sun's disk on the left, so that the edges of the sun and Venus perfectly coincided, forming an angle of contact." I pass over his observations, to quote his account of the feelings with which Crabtree witnessed the spectacle of "Venus on the sun's face." "I had written," he says, "to my most esteemed friend William Crabtree, a person who has few superiors in mathematical learning, inviting him to be present at this Uranian banquet, if the weather permitted; and my letter, which arrived in good time, found him ready to oblige me. . . . But the sky was very unfavorable, being obscured during the greater part of the day with thick clouds; and, as he was unable to obtain a view of the sun, he despaired of making an observation, and resolved to take no further trouble in the matter. But a little before sunset—namely, about thirty-five minutes past three—the sun bursting forth from behind the clouds, he at once began to observe, and was gratified by beholding the pleasing spectacle of Venus upon the sun's disk. Rapt in contemplation, he stood for some time motionless, scarcely trusting his own senses, through excess of joy; for we astronomers have, as it were, a womanish disposition, and are overjoyed with trifles, and such small matters as scarcely make an impression upon others; a susceptibility which those who will may deride with impunity, even in my own presence; and, if it gratify them, I too will join in the merriment. One thing I request: let no severe Cato be seriously offended with our follies; for, to speak poetically, what young man on earth would not, like ourselves, fondly admire Venus in conjunction with the sun, *pulchritudinem divitiis conjunctam?*"

Many years passed before another transit of Venus took place. This was the transit of 1761, and it affords striking evidence of the interest with which, even at this early epoch, astronomers regarded the transits of Venus, that Dr. Halley, the first Astronomer Royal, prepared a dissertation on the subject of the transit of 1761 forty-five years before it took place. Considering all the circumstances, he made a very fair prediction—in fact, the calculated time when Venus was to be at her nearest to the middle of the sun's face was only about half an hour in error, whereas the epochs first announced by our present Astronomer Royal for the entrance and exit of Venus during the transit of 1874 were one hour and three-quarters of an hour, respectively, in error. I do not propose here, however, to touch on any of the mathematical matters dealt with by Halley, and I shall content myself with quoting the remarks which he made on the importance of observing Venus with due care for the sake of determining the sun's distance:

"I could wish," he says (I follow Ferguson's translation), "that many observations of the same phenomenon might be taken by different persons at several places, both that we might arrive at a greater degree of certainty by their agreement, and also lest any single observer should be deprived by the intervention of clouds of a sight which I know not whether any man living in this or the next age will ever see again, and on which depends the certain and adequate solution of a problem the most noble, and at any other time not to be attained to. I recommend it, therefore, again and again to those curious astronomers who (when I am dead) will have an opportunity of observing these things, that they would remember this my admonition, and diligently apply themselves with all their might to the making this observation; and I earnestly wish them all imaginable success; in the first place, that they may not, by the unseasonable obscurity of a cloudy sky, be deprived of this most desirable sight; and then that, having ascertained with more exactness the magnitudes of the planetary orbits, it may redound to their immortal fame and glory."

A few years before the transit of 1761, Delisle, the French astronomer, undertook a careful analysis of all the circumstances of the approaching phenomenon. It had been ascertained that the transit of 1761 was only the first of a pair of transits, the second occurring in 1769; and it was found that the method by which Halley had proposed to utilize the earlier transit would not, on this occasion, be altogether suitable. I shall presently describe the methods respectively suggested, but it is necessary to mention them here, in order that the chronological sequence of the events may be recognized. For many who have heard Delisle's method lately spoken of and insisted upon (as in Parliament by Mr. Goschen) have been led to imagine that it is a recent invention, and, again, that it possesses great advantages over Halley's, whereas it was known and discussed before the transits of 1761 and 1769, and, while very properly adopted for the first transit, was as properly superseded by Halley's in the case of the second.

The transit of 1761 (like that which will occur on December 6, 1882) was partially visible in England. It was observed at Greenwich by the Rev. M. Bliss, Astronomer Royal, and at Savile House, near London, by Mr. Short, "in presence," says the account, "of his Royal Highness the Duke of York, accompanied by their Royal Highnesses Prince William, Prince Henry, and Prince Frederick." A great number of observations[1] were made also in different parts of the world, and a sufficiently satisfactory determination of the sun's distance was deduced therefrom.

It was, however, in 1769, that the real attack was made. It was then that the famous expedition of Captain Cook, in the Endeavor, was made, England being the only country which had a station in the Pacific. The arctic regions were visited also, a station being selected at Wardhus, in North Lapland, where the following notable peculiar-

[1] There were 63 observing-stations in all, thus distributed: 13 in North Europe, 8 in England, 15 in France, 6 in Spain, Portugal, and Italy, 16 in Germany, and 3 in other places.

ity was presented—the beginning of the transit was observed before sunset, and the end after sunrise. There were also stations at Kola, Yakutsk in Siberia, Peking, Manila, Batavia, Hudson's Bay, St. Petersburg, St. Joseph in California, and many other places. In all there were no less than 74 observing-stations, whereof 50 were in Europe.

The reader need hardly be reminded that the determination of the sun's distance which was until lately in use in our text-books of astronomy was based on the observations made during the transit of Venus in 1769. Nevertheless it has been shown that those observations, rightly interpreted, give a determination of the sun's distance according well with those which have been obtained by the best modern methods, whether these have depended on observations of the sun himself, or the moon, or Mars—or, lastly, of the swift flight of light.

EVOLUTION AND MIND.[1]

By C. B. RADCLIFFE, M.D., F.R.C.P.

WITH Mr. Herbert Spencer I have much sympathy, and yet I can not be content to stay at the end at which he arrives and stays. I thoroughly sympathize in his belief that all true philosophical reasoning has its end in unity—that there are abundant proofs of this unity in matter and spirit, in things visible and things invisible—that the truths of science and religion find reconciliation in this unity. I reject, as he does, a purely spiritualistic view of things no less than a purely materialistic view. But I cannot agree with him in believing in indefinite evolution. Nor can I agree with him in believing that life and mind are to be interpreted in terms of matter, motion, and force, even though this interpretation be taken as only symbolizing provisionally arbitrary aspects of an Unknown Reality; and least of all can I agree with him in believing that the principle of unity, underlying matter and spirit alike, is merely an Unknown Cause, the Unknowable, a Power without limits of either time or space, of which the nature ever remains inconceivable. Much, no doubt, is of necessity unknowable, but I would not place the limits of thought where Mr. Spencer would place them. On the contrary, I would hold that there is nothing *unreasonable* in widening these limits so as to bring within them an actual God, even the God of the Scriptures, and that by so doing a much more *reasonable* realization of unity is to be found than that which can be found in an Unknown Reality. I would hold, indeed, that the nature of the Unknowable is to be encroached upon in this way, and to this extent, by the power of the reason, and also that

[1] Part of lecture delivered before the Royal College of Physicians, March, 1873.

there is nothing in the speculations to which I am now referring which can stamp as *unreasonable* that particular view of mind and body which it is the object of this lecture to set forth cursorily.

But what of that view of mind which arises out of the doctrine with which the name of Mr. Darwin is at present especially connected —a name which must always command the highest respect of all *naturalists?* Is not the view arising out of the doctrine of evolution altogether at variance with that which I have been led to take in this lecture? Unquestionably so. It is simply impossible to reconcile the two views; and it is also certain that, if that which arises out of the doctrine of evolution be right, the other must be abandoned. What, then, are the facts upon which this doctrine of evolution is based? This is the question. Are they to be read only in favor of this doctrine, or is there another reading? I venture to think that there is another reading; but how can I make good this statement with the hands of the clock standing where they do! At most I can only throw out a hint or two of what I might say on the subject if I had the time, and this is all I propose to do.

No one can believe more firmly than I do that there is a common plan in all animals and in all parts of animals, as well as in all plants and in all parts of plants, or that there is a common unity for the whole organic world, plant and animal alike. No one can believe more firmly than I do that there are manifestations of mind, not dissimilar in kind to human mind, in the brute creation, and that the law of mind is one and the same everywhere. But it does not follow from this belief in unity that I should believe that one organ should be developed into another organ, or one animal or plant into another animal or plant. The doctrine of unity is quite consistent with a belief that there are certain fixed differences in organs or organisms; it has nothing to do with the doctrine of evolution, except, perhaps, in making its acceptance a little less difficult, for it is a little more easy to suppose that a higher creature may be evolved from a lower if there be the same archetypal unity of plan underlying the two; more than this it cannot do.

I cannot doubt that in the embryonic life of the higher animals there is a process of development at work by which the embryo before arriving at maturity passes through certain stages which seem to shadow forth certain permanent states of being lower down in the scale of life. I cannot doubt that in this case the more perfect is preceded by the more crude, and that there is a process of evolution at work up to a given point. But what follows? Certainly not this—that these resemblances are realities, that the embryo of a higher animal, in developing to maturity, passed through a succession of different animals each one a little more perfect than its predecessors. Certainly not more than this—that the higher animal in the embryonic period of its history, without ever ceasing to be itself, passes through certain stages of development in which there are certain *likenesses*, never very close, to certain forms of animal life lower down than itself in the scale of being—likenesses which simply bear witness to the unity of plan in all forms of animal life.

I also find it difficult to twist the marvellous improvability of man into an argument for the doctrine of evolution. Who shall say that this improvability is not restricted within certain prescribed limits? As yet man, in his struggle for life, has never turned his opportunities for natural selection so far to account as to make even the slightest advance toward physical improvement. And it is possible that the change for the better which is actually witnessed in man may have to be explained in accordance with the Scriptures rather than in accordance with the doctrine of evolution.

Nor can I rest satisfied with what may be spoken of as the more special evidence in favor of evolution. The pigeon, by developing under cultivation into what may be considered as improved varieties of pigeon, may at first seem to be the subject of evolution; but the changes produced in this way are never more than those minor changes which go to make up the differences called *varieties*, never so great as to constitute another *species* of bird. Moreover, only let the varieties thus produced be let alone for a few generations, and the inevitable result is a return to the original form of the common pigeon, if not to that of the wild, blue rock-pigeon. The history contradicts the notion of evolution rather than confirms it. And so with the dog or any other animal which may be modified as the pigeon is modified; the change produced is never beyond that of mere *variety*, never into that of a new *species;* and let the constraining influences which brought it about come to an end, and, as with the pigeon, it is not long before the original wild form has again cropped out. And what other conclusion can be fairly drawn from the infertility of mules than this—that there is a barrier between different species of animals, even between those which are most closely akin to each other, by which one is prevented from passing into the other. Nay, it is even difficult to find any evidence in favor of evolution in the history of the rudimentary creatures which swarm in dense crowds around the very feet of the scale of being. Here are wonderful changes at work by which, as Dr. Bastian so clearly demonstrates, *bacteria*, the simplest of all living units, may be developed, possibly from inorganic elements, almost at the will of the experimenter, into *monads*, and *amœbœ*, and *paramecia*, or into the lowest forms of *fungus*—into forms of animal life, that is to say, or into forms of vegetable life; but not much is to be built upon this fact in favor of evolution. For what follows? Simply this—that these forms are unstable in the highest degree, and that, instead of passing on into higher forms of being, they presently again break up into their original bacterial units, which units are destined again and again to go through the same narrow round of combining and separating. The evolution, if evolution it be, is kept within the narrowest limits; the tendency to retrograde is quite as marked as the tendency to go forward; and, as respects evolution, the conclusion to be drawn is even that which has been drawn from the changes witnessed in the pigeon and the dog—this and no other. It may be questioned, also, whether this doctrine of evolution derives as much support as it is supposed to do from the facts belonging to astronomy and geology.

The nebular hypothesis, which may be taken as the real starting-point of the doctrine in question, is certainly very nebulous. The facts upon which it is founded show unity of plan; of that there need be no doubt; but this unity of plan is really a matter quite apart from the nebular hypothesis founded upon it. Besides, where did the heat come from which kept up the nebulous state which preceded the formation of the heavenly bodies of various sorts, and what has become of it since the time of this formation? What real proof is there of the continual cooling which should still be going on according to this view? Like light and gravity, heat may result in the mutual reactions of the heavenly bodies, or be a property of one or other of these bodies; but to conceive of it as independent of these bodies is, to say the least, no easy matter. Indeed, so difficult is it so to conceive of it, that, until the difficulty is overcome, the nebular hypothesis may be set aside as a dream which is as little calculated to give probability to the doctrine of evolution as the evidence which has been already glanced at.

And so likewise with that particular evidence in favor of evolution which the facts of geology are supposed to supply. Endless ages are needed to allow of evolution; and the facts of geology are believed to testify unequivocally to the lapse of these ages. But is it so? If the rock in which the skeleton of a plesiosaurus is embedded had been deposited as slowly as it is supposed to have been deposited, every trace of organization must have decomposed and disappeared long ages before the animal could have been covered up in its bed. For the skeleton to be there at all, indeed, is a plain proof that the rock, at least to the thickness needed for embedding it, must have been deposited before decomposition had time to do its work fully. And so likewise in every other analogous case. Nay, it may even be questioned whether there has been a separate upheaval and sinking to allow of the formation of each coal-seam or limestone-bed, for many of these seams and beds which are parallel may have to be explained as *drifts*, which have to do with *one* cataclysm of upheaval and sinking rather than with *many* such cataclysms, for how could this strict parallelism be preserved if there had been many cataclysms? Moreover, it must not be forgotten that there are not a few fossils out of place in the strata, fossils which ought not to be where they are if living things had made their appearance on the earth in the order required by the doctrine of evolution.

In a word, I fail to find anywhere sufficient reason for believing that man began his history as a marine ascidian, or as a creature still lower down in the scale of being, and that he has worked his way to his present state of civilization by ceaseless strugglings upward—first, in countless forms of brute life, each one succeeding in the series being a little more advanced than that which went before it; and then through an interminable line of savage ancestry, of which the first in the series was only a shade more advanced than the tailless ape of which he was the immediate descendant. And glad I am that it is so; for this idea of imperfect being ever, and almost forever, straining after perfection, and constantly failing in the struggle, produces a feeling approaching to a painful shudder. At any rate, until these and other difficulties are swept away, I find it more easy to accept the doctrine of the creation than to accept the doctrine of evolution, and to believe that each creature was created perfect in itself, and in its relations to all other creatures, and to the universe of which it is a necessary part—so perfect as to deserve to be spoken of at the beginning as "very good"—and that man originally was no brute-descended savage, living in a wilderness, and fighting his way step by step upward to a higher level, but a demi-god, walking and talking in a paradise with the God in whose image he was made, until, for some fault of his own, he was driven out into the wilderness, a slave to body, naked, and all but altogether oblivious of every thing relating to his high original.—*London Lancet.*

IN QUEST OF THE POLE.

FOUR centuries ago the great commercial question of Western Europe related to a new way of getting to the Indies. Columbus struck boldly westward to solve the problem, and, when he encountered land, supposed he had solved it; and named the country India, and the people Indians. But it was at length found that the supposed discovery of Columbus was an illusion, and that a great, new continent barred the way to India. Nothing remained, then, but to go round it if possible, and so navigators struck for a northwest passage. The Cabots traced the American coast from Virginia to Labrador, and attempted to make the passage to India by the north. They failed, and navigators then tried the northeast passage, and, disappointed there, after many years, they turned back again to the alternative route. In May, 1501, Gasper Vasco sailed from Lisbon with two ships to accomplish the northwest passage. These parted company in a storm off the Greenland coast, and Vasco's ship was never heard of again. The next year a brother of Gasper went in search of him with three ships; the expedition failed, however, and but two ships returned.

In 1576 Martin Frobisher, after begging money of merchants for 15 years to undertake "the only great thing left undone in the world," got off with two small vessels, one of 25 tons and one of 10, and reached Labrador in safety, discovering the strait which is called by his name; but he accomplished nothing more.

In 1585 Captain John Davis started for the northwest with two ships, and got as far as latitude 70°, discovering the strait which bears his name.

In 1607 Henry Hudson was commissioned by certain London merchants to find a route to India across the pole, and, in a little vessel manned by 10 men and one boy, reached the east coast of Greenland, in latitude 70°. He had gone beyond the 80th parallel before his way was blocked by the ice. He made several voyages, the last in 1610 in an ill-provisioned ship and with an unruly crew; but he made his way through the strait and into the bay which bear his name. He was frozen in during the winter; his mutinous crew took control of the ship, and set him adrift in an open boat with his little son and six invalid seamen, and they were never heard of again. After this, expeditions followed rapidly, led by Poole, Button, Bylot, Baffin, Munck, and others. After 1631 little was done in this direction for a century. There was a revival of adventure between 1741 and 1746, but ill-success again discouraged efforts for more than half a century. In 1773 Lord Musgrave attempted to reach the pole, and in 1776 Captain Cook tried to circumnavigate the northern shore of America by way of Behring's Strait.

With the opening of the present century arctic enterprise began to assume a new phase, and was pursued more in the interest of science. If the northwest passage was impossible, it was determined to find out how much was possible in exploring the northern region. To reach the magnetic and geographical poles, and ascertain the conditions of the polar sea and the accompanying phenomena, were now the main objects of adventure. Captain Scoresby, in 1806, reached a point north of Spitzbergen in latitude 81° 30′—510 geographical miles from the pole. He saw an open sea before him, but his vessel was only a whaler, and he was answerable to her owners, so he reluctantly turned back. In 1818 two expeditions sailed—Buchan's and Ross and Parry's. In 1819 Parry set out again, and discovered Prince Regent's Inlet, Barrow Strait, Wellington Channel, Melville Sound, and wintered at Melville Island. Clavering's expedition (1823), Grabb's (1828, Danish), De Blosseville's (1833, French), and Parry's third (1827), were strictly for the purposes of scientific exploration, and not for the discovery of the northwest passage. Sir John Franklin commenced his career as a northern navigator with Captain Buchan, in 1818, as a lieutenant. In 1819, in connection with Dr. Richardson, he set out from Fort

York, Hudson's Bay, on an overland expedition to circumnavigate the northern coast. They were accompanied by Midshipman George Back, afterward Captain Back, a courageous and enterprising explorer. In 1825 Franklin, Richardson, and Back, again set out on an overland expedition for surveying the northern coast. In 1829 Captain John Ross entered Prince Regent's Inlet, and, after surveying the coast of the Boothian Peninsula, he went into winter-quarters. In the spring of 1831 his nephew, James Ross, discovered the north magnetic pole.

In 1837 the coast between Return Reef and Point Barrow was surveyed by Dean and Simpson, in the service of the Hudson's Bay Company. Simpson was the soul of the expedition, and had already made a tramp of over 2,000 miles through the wilderness, and in the depth of winter. Simpson afterward continued the survey, and accomplished a boat-voyage of over 1,600 miles. He died, at the age of thirty-six, by the hand of an Indian assassin.

Sir John Franklin set out on his last voyage in 1845, being then in his sixtieth year, with two ships, the Erebus and the Terror. These vessels were last spoken, July 26th, in the same year, in Baffin's Bay, latitude 77°. In 1848 commenced the *search* for Franklin. The Plover and Hecla took out supplies for him to Behring's Strait. His old companion Richardson went out the same year, as did also Sir James Ross and Captain Bird. In 1850 twelve ships joined in the search, and in 1852 six vessels sailed from England on the same errand. McClure, commanding the Investigator, passed through Behring's Strait in 1850, and safely reached Marcy Bay in 1852, thus discovering the northwest passage. McClintock at length, in the spring of 1859, learned from a party of Esquimaux, on the southwest coast of Boothia-Felix, the mournful story of the fate of Franklin and his men.

Elisha Kent Kane accompanied the first Grinnell expedition (Advance, Lieutenant De Haven) in 1850–'51, and was commander of that vessel in the second Grinnell expedition in 1853. On August 7th he entered Smith's Sound, and, after encountering fearful perils, found a harbor in Rensselaer Bay, latitude 78° 38′. The Advance was fated never to come out of that bay, and had to be abandoned there two years later. April 25, 1854, he set out on a sledge-journey northward, drawn by dogs. May 4th he saw Great Humboldt glacier, and, though scurvy, cold, and dropsy, had wasted his strength, he would still have insisted on advancing, but he now became delirious, and his companions turned their faces shipward. On August 24th, when it was seen that there was no hope of getting the ship free from the ice, Kane called his officers and men together and announced his determination to remain. They were in all 17, and of these nine chose to leave their commander and essay a return home. Kane now adopted the Esquimaux form of house and the Esquimaux diet, as best suited to the climate. He also entered into friendly relations with the natives;

and thus he was enabled to live with comparative comfort in that high latitude. The deserters returned, in great distress, December 12th, the thermometer being then 50° below zero. The entire party abandoned the ship May 20, 1855, and set out on their long journey homeward. They reached New York October 11th.

Dr. Hayes was with Kane in his second voyage, and in 1860 commanded an expedition himself, intending to reach the pole. He took up his winter-quarters at Port Foulke, in Smith's Sound, and penetrated as far north as 82° 45′ on sledges. Dr. Hayes again visited Greenland in the following year, but restricted his labors to the survey of the southern coasts of the peninsula.

The last great polar expedition, which has just closed so eventfully, was in command of Captain Charles Francis Hall, who was born in Cincinnati in 1825. He was apprenticed in early life to a blacksmith, and worked for a time at his trade. He was a man of vigorous and robust development, of courteous and agreeable manners, and, although without a regular scientific education, he had an acute and practical mind. Without having studied the science of navigation, he took to it with enthusiasm, and by tact and experience became a competent commander. In his first voyage (1860) he spent two years and three months in the arctic regions. He went out again in 1864, and stayed five years, and then fully ascertained the time and places where the Franklin company had perished. His last expedition was fitted out by the United States Government, and he sailed from New York June 29, 1871, in the ship Polaris, his object being to find the north-pole. She took supplies from the United States ship Congress at Disco, in Greenland, and in August Captain Hall bade adieu to civilization at Tussisack, and pushed on toward the pole, while for nearly two years nothing was heard from him. A portion of the crew have now returned, from whom we learn that the ship reached latitude 82° 16′, but put back and took up winter-quarters in latitude 81° 38′, and there she was frozen up. On October 10th Captain Hall started on an expedition north, with sledges drawn by Esquimaux dogs, and accompanied by the mate and two Esquimaux. The party was absent two weeks, and returned to the ship on October 24th. Captain Hall was immediately taken sick, and, after fifteen days' illness, he died November 8, 1871. The following year, on August 12th, the Polaris left winter-quarters, got on her beam ends on the 15th of the same month, and was driven south to latitude 77° 35′, when, owing to the heavy pressure of the ice, the vessel was thrown up, and while landing stores broke from her moorings October 15th, with a part of the crew, and drifted away. The party remaining on the ice consisted of 19 persons, five of whom were women and children. They had two boats, and a stock of provisions sufficient for a month, which, by short rations, they determined to make last for five months. One of the boats was used for fuel, and there were no materials for fire. Snow-huts were erected on the ice-

JOHN STUART MILL.

floe, which drifted southward, and was frequently broken up by storms. To add to the horror of their situation, the arctic night set in—the sun disappearing early in December, and not reappearing until the end of January—day being distinguishable from night only by the diurnal streak of light which appeared on the southern horizon. Fortunately the party had rifles and ammunition, and prolonged their lives by killing a few seals, bears, and birds. This life of almost indescribable suffering was continued for over six months, or 197 days. They were at last rescued off Newfoundland by the British steamer Tigress, after having drifted in winter upon the ice a distance of more than 1,500 miles. That the party all survived, and were saved at last in good health, was attributed to the admirable discipline of the company under the intrepid management of Captain Tyson. Of the scientific results of the expedition we as yet know little, but shall perhaps learn more when the Polaris, in charge of Captain Buddington, returns, as she is expected to do this summer.

JOHN STUART MILL.

JOHN STUART MILL, the great English philosopher, is no more. He was born in London, May 20, 1806, and was consequently near sixty-seven years old at the time of his death. His father was James Mill, a man of philosophical intellect and wide attainments, and author of two celebrated works, "The History of British India," and "The Phenomena of the Human Mind." Instead of being sent to school, the son was carefully educated at home under his father's supervision, and in accordance with his ideas. His early education was thoroughly classical, and he was led into the paths of philosophical inquiry in which his father was distinguished. The elder Mill had long been employed in the service of the East India House, and, in 1823, when the son was seventeen years old, his father secured for him a position in the same establishment, which he continued to hold for 35 years. He thus early came in possession of more than a competence, and with abundant leisure to cultivate the rare resources of his mind, and to take his place as a leader of modern thought. While yet a very young man, he contributed various essays of a bold and thoughtful character to the *Edinburgh* and *Westminster Reviews*, and, some years later, he became editor and proprietor of the latter periodical. In 1843, when he was thirty-eight years old, he published the great work which established his world-wide reputation, "The System of Logic;" and, in 1848, appeared his elaborate treatise, "The Principles of Political Economy." In 1851, at the age of forty-five, he married Harriet, daughter of Thomas Hardy, Esq., and widow of John Taylor, a London merchant. His wife died at Avignon, in the south of France, in 1858. She was buried there, and her husband raised a monument to her memory, and has since resided there much of his time. He also died at Avignon, and rests in the tomb beside his beloved wife. In 1859 appeared his "Essay on Liberty," and his "Discussions and Dissertations" in 1860. In 1865, when in his sixtieth year, Mr. Mill was elected to Parliament from the district of Westminster, in London, and he was again a candidate, in 1868, in the constituency of Westminster, but was beaten by a rich Tory news-dealer. His work entitled "Considerations on Representative Government" appeared in 1861, and that on "Utilitarianism" in 1863. The work upon which his reputation as a metaphysician will chiefly rest is "The Examination of Sir William Hamilton's Philosophy," published in 1865. In 1869 appeared his little book on the "Subjection of Woman," and his last production, a review of Grote's unfinished "Aristotle," appeared in the *Fortnightly Review* for January of the present year.

In personal appearance Mr. Mill was slight in form, of medium height, somewhat stooping, with a bald head and a conspicuous wen on the left side of the forehead. His small gray eyes were penetrating and restless, and the nose aquiline and prominent. He had thin, compressed lips, with a very decided but agreeable expression of mouth. His face was clean-shaven and bloodless, and he had a perpetual nervous movement—a sort of twitching of the lips and eyes. His manners were unassuming and agreeable, but somewhat diffident and constrained. There was a nervous uncertainty in his movements which at first suggested lameness. He had a thin, weak voice, and spoke at times with a partial stammer. Although no orator, he was a clear, self-possessed, and forcible public speaker, who relied upon argument rather than rhetoric to impress his hearers. In temperament he was far from being the cold, intellectual machine which the readers of his "Logic" might suppose him to be. His nature was sympathetic, and capable of strong attachments, and he could hate his enemies as well as love his friends.

The following sketches and estimates of Mr. Mill's career and character are from the London *Examiner*, which issued a memorial number. Some of the minor contributions have been omitted, and others slightly condensed; but those herewith published form a very valuable summary of Mr. Mill's traits and labors·

HIS EDUCATION AND MARRIAGE.

BY H. R. FOX BOURNE.

James Mill was living in a house at Pentonville when his son was born; and, partly because of the peculiar abilities that the boy displayed from the first, partly because he could not afford to procure for him elsewhere such teaching as he was able himself to give him, he took his education entirely into his own hands. With what interest—even jealous interest, it would seem—Bentham watched that education, appears from a pleasant little letter addressed to him by the elder Mill in 1812. "I am not going to die," he wrote, "notwithstanding your zeal to come in for a legacy. However, if I were to die any time before this poor boy is a man, one of the things that would pinch me most sorely would be the being obliged to leave his mind unmade to the degree of excellence of which I hope to make it. But another thing is, that the only prospect which would lessen that pain would be the leaving him in your hands. I, therefore, take your offer quite seriously, and stipulate merely that it shall be made as soon as possible, and then we may perhaps leave him a successor worthy of both of us." It was a bold hope, but one destined to be fully realized. At the time of its utterance, the "poor boy" was barely more than six years old. The intellectual powers of which he gave such early proof were carefully, but apparently not excessively, cultivated. Mrs. Grote, in her lately-published "Personal Life of George Grote," has described him as he appeared in 1817, the year in which her husband made the acquaintance of his father: "John Stuart Mill, then a boy of about twelve years old"—he was really only eleven—"was studying, with his father as his sole preceptor, under the paternal roof. Unquestionably forward for his years, and already possessed of a competent knowledge of Greek and Latin, as well as of some subordinate though solid attainments, John was, as a boy, somewhat repressed by the elder Mill, and seldom took any share in the conversation carried on by the society frequenting the house." It is, perhaps, not strange that a boy of eleven, at any rate a boy who was to become so modest a man, should not take much part in general conversation, and Mr. Mill himself never, in referring to his father, led his hearers to suppose that he had, as a child, been in any way unduly repressed by him. The tender affection with which he always cherished his father's memory in no way sanctions the belief that he was at any time subjected to unreasonable discipline. By him his father was only revered as the best and kindest of teachers.

The lad was, in the summer of 1820, sent to France for a year and a half. For several months he lived in Paris, in the house of Jean Baptiste Say, the political economist. The rest of his time was passed in the company of Sir Samuel Bentham, Jeremy Bentham's brother. Early in 1822, before he was eighteen, he returned to London, soon to enter the India Office as a clerk in the department of which his father was chief. In that office he remained for five-and-thirty years, acquitting himself with great ability, and gradually rising to the most responsible position that could be held there by a subordinate.

But, though he was thus early started in life as a city-clerk, his self-training and his education by his father were by no means abandoned. The ancient and modern languages, as well as the various branches of philosophy and philosophical thought in which he was afterward to attain such eminence, were studied by him in the early mornings, under the guidance of his father, before going down to pass his days in the India Office. During the summer evenings, and on such holidays as he could get, he began those pedestrian exploits for which he afterward became famous, and in which his main pleasure appears to have consisted in collecting plants and flowers in aid of the botanical studies that were his favorite pastime, and something more, all through his life. That he worked early and with wonderful ability in at least one very deep line appears from the fact that, while he was still only a lad, Jeremy Bentham intrusted to him the preparation for the press, and the supplementary annotation, of his "Rationale of Judicial Evidence." That work, for which he was highly commended by its author, published in 1827, contains the first publicly-acknowledged literary work of John Stuart Mill. While he was producing that result of laborious study in a special and intricate subject, his education in all sorts of other ways was continued.

A writer in the *Times* remarks: "He was, by all accounts, an extraordinary child; and it is within our personal knowledge that he was an extraordinary youth when, in 1824, he took the lead at the London Debating Club in one of the most remarkable collections of 'spirits of the age' that ever congregated for intellectual gladiatorship, he being by two or three years the junior of the clique. The rivalry was rather in knowledge and reasoning than in eloquence; mere declamation was discouraged; and subjects of paramount importance were conscientiously thought out."

Having retired from the India House in 1858, Mr. Mill went to spend the winter in Avignon, in the hope of improving the broken health of the wife to whom he was devotedly attached. He had not been married many years, but Mrs. Mill had been his friend since 1835. During more than twenty years he had been aided by her talents and encouraged by her sympathy in all the work he had undertaken, and to her rare merits he afterward paid more than one tribute in terms that have no equal for the intensity of their language and the depth of affection contained in them. Mrs. Mill's weak state of health seems to have hardly repressed her powers of intellect. By her was written the celebrated essay on "The Enfranchisement of Women" contributed to the *Westminster Review*, and afterward reprinted in the "Dissertations and Discussions," with a preface avowing that by her Mr. Mill had been greatly assisted in all that he had written for some time previous. But the assistance was to end now. Mrs. Mill died at Avignon, November 3, 1858, and over her grave was placed one of the most pathetic and eloquent epitaphs that have been ever penned. "Her great and loving heart, her noble soul, her clear, powerful, original, and comprehensive intellect," it was there written, "made her the guide and support, the instructor in wisdom, and the example in goodness, as she was the sole earthly delight, of those who had the happiness to belong to her. As earnest for all public good as she was generous and devoted to all who surrounded her, her influence has been felt in many of the greatest improvements of the age, and will be in those still to come. Were there even a few hearts and intellects like hers, this earth would already become the hoped-for heaven." Henceforth, during the fourteen years and a half that were to elapse before he should be laid in the same grave, Avignon was the chosen haunt of Mr. Mill.

Passing much of his time in the modest house that he had bought, that he might be within sight of his wife's tomb, Mr. Mill was also frequently in London, whither he came especially to facilitate the new course of philosophical and political writing on which he entered. He found relief also in excursions, one of which was taken nearly every year, in company with his step-daughter, Miss Helen Taylor, into various parts of Europe. Italy, Switzerland, and many other districts were explored, partly on foot with a keen eye both to the natural features of the localities, especially in furtherance of those botanical studies to which Mr. Mill now returned with the ardor of his youth, and also to their social and political institutions.

HIS CAREER IN THE INDIA HOUSE.

BY W. T. THORNTON.

In 1823 the illustrious subject of these brief memoirs, then a lad of seventeen, obtained a clerkship under his father. According to the ordinary course of things in those days, the newly-appointed junior would have had nothing to do, except a little abstracting, indexing, and searching or pretending to search into records; but young Mill was almost immediately set to indite dispatches to the governments of the three Indian Presidencies, on what, in India House phraseology, were distinguished as "political" subjects—subjects, that is, for the most part growing out of the relations of the said governments with "native" states or foreign potentates. This continued to be his business almost to the last. In 1828 he was promoted to be Assistant Examiner, and in 1856 he succeeded to the post of Chief Examiner, after which his duty consisted rather in supervising what his Assistants had written than in writing himself; but, for the three-and-twenty years preceding, he had had immediate charge of the Political Department, and had written almost every "political" dispatch of any importance that conveyed the instructions of the merchant princes of Leadenhall Street to their proconsuls in Asia. Of the quality of these documents it is sufficient to say that they were John Mill's; but, in respect to their quantity, it may be worth mentioning that a descriptive catalogue of them completely fills a small quarto volume of between 300 and 400 pages, in their author's handwriting, which now lies before me; also that the share of the Court of Directors in the correspondence between themselves and the Indian governments used to average annually about ten huge vellum-bound volumes, foolscap size, and five or six inches thick, and that of these volumes two a year, for more than than twenty years running, were exclusively of Mill's composition; this, too, at times when he was engaged upon such voluntary work in addition as his "Logic" and "Political Economy."

In 1857 broke out the Sepoy war, and in the following year the East India Company was extinguished in all but the name, its governmental functions being transferred to the crown. That most illustrious of corporations died hard, and with what affectionate loyalty Mill struggled to avert its fate is evidenced by the famous petition to Parliament which he drew up for his old masters, and which opens with the following effective antithesis: "Your petitioners, at their own expense, and by the agency of their own civil and military servants, originally acquired for this country its magnificent empire in the East. The foundations of this empire were laid by your petitioners at that time, neither aided nor controlled by Parliament, at the same period at which a succession of administrations under the control of Parliament, were losing by their incapacity and rashness, another great empire on the opposite side of the Atlantic."

I am fortunate enough to be the possessor of the original MS. of this admirable state paper, which I mention, because I once heard its real authorship denied in that quarter of all others in which it might have been supposed to be least likely to be questioned. On one of the last occasions of the gathering together of the proprietors of East India stock, I could scarcely believe my ears, when one of the directors, alluding to the petition, spoke of it as having been written by a certain other official who was sitting by his side, adding after a moment's pause, "with the assistance as he understood, of Mr. Mill," likewise present. As soon as the court broke up, I burst into Mill's room, boiling over with indignation, and exclaiming, "What an infamous shame!" and no doubt adding a good deal more than followed in natural sequence on such an exordium. "What's the matter?" replied Mill, as soon as he could get a word in, "M—— (the director) was quite right. The petition was the joint work of —— and myself." "How can you be so perverse?" I retorted. "You know that I know you wrote every word of it." "No," rejoined Mill, "you are mistaken; one whole line on the second page was put in by ——."

The nearest approach made, throughout our intercourse, to any thing of an unpleasant character, was about the time of his retirement from the India House. Talking over that one day, with two or three of my colleagues, I said it would not do to let Mill go without receiving some permanently visible token of our regard. The motion was no sooner made than it was carried by acclamation. Every member of the Examiner's office—for we jealously insisted on confining the affair to ourselves—came tendering his subscription, scarcely waiting to be asked; in half an hour's time some £50 or £60—I forget the exact sum—was collected, which, in due course, was invested in a superb silver inkstand, designed by our friend Digby Wyatt, and manufactured by Messrs. Elkington. Before it was ready, however, an unexpected trouble arose. In some way or other, Mill had got wind of our proceeding, and, coming to me in consequence, began almost to upbraid me as its originator. I had never before seen him so angry. He hated all such demonstrations, he said, and was quite resolved not to be made the subject of them. He was sure they were never altogether genuine or spontaneous. There were always several persons who took part in them, merely because they did not like to refuse, and in short, whatever we might do, he would have none of it. In vain I represented how eagerly everybody, without exception, had come forward; that we had now gone too far to recede; that if he would not take the inkstand, we should be utterly at a loss what to do with it, and that I myself should be in a specially embarrassing position. Mill was not to be moved. This was a question of principle, and on principle he could not give way. There was nothing left, therefore, but resort to a species of force. I arranged with Messrs. Elkington that our little testimonial should be taken down to Mr. Mill's house at Blackheath, by one of their men, who, after leaving it with the servant, should hurry away without waiting for an answer. This plan succeeded, but I have always suspected, though she never told me so, that its success was mainly due to Miss Helen Taylor's good offices. But for her, the inkstand would almost certainly have been returned, instead of being promoted, as it eventually was, to a place of honor in her own and her father's drawing-room.

HIS MORAL CHARACTER.

BY HERBERT SPENCER.

To dilate upon Mr. Mill's achievements, and to insist upon the wideness of his influence over the thought of his time, and consequently over the actions of his time, seem to me scarcely needful. The facts are sufficiently obvious; and are recognized by all who know any thing about the progress of opinion during the last half-century. My own estimate of him, intellectually considered, has been emphatically, though briefly, given on an occasion of controversy between us, by expressing my regret at "having to contend against the doctrine of one whose agreement I should value more than that of any other thinker."

While, however, it is almost superfluous to assert of him that intellectual height so generally admitted, there is more occasion for drawing attention to a moral elevation that is less recognized, partly because his activities in many directions afforded no occasion for exhibiting it, and partly because some of its most remarkable manifestations in conduct are known only to those whose personal relations with him have called them forth. I feel especially prompted to say something on this point, because, where better things might have been expected, there has been, not only a grudging recognition of intellectual rank, but a marked blindness to those fine traits of character which, in the valuation of men, must go for more than superiority of intelligence.

It might, indeed, have been supposed that even those who never enjoyed the pleasure of personal acquaintance with Mr. Mill, would have been impressed with the nobility of his nature as indicated in his opinions and deeds. How entirely his public career has been determined by a pure and strong sympathy for his fellow-men—how entirely this sympathy has subordinated all desires for personal advantage—how little even the fear of being injured in reputation or position has deterred him from taking the course which he thought equitable or generous—ought to be manifest to every antagonist, however bitter. A generosity that might almost be called romantic was obviously the feeling prompting sundry of those courses of action which have been commented upon as errors. And nothing like a true conception of him can be formed unless, along with dissent from them, there goes recognition of the fact that they resulted from the eagerness of a noble nature, impatient to rectify injustice, and to further human welfare.

It may, therefore, perhaps, be that my own perception of this pervading warmth of feeling has been sharpened by seeing it exemplified, not in the form of expressed opinions only, but in the form of private actions. For Mr. Mill was not one of those who, to sympathy with their fellow-men in the abstract, join indifference to them in the concrete. There came from him generous acts that corresponded with his generous sentiments. I say this not from second-hand knowledge, but having in mind a remarkable example known only to myself and a few friends. I have hesitated whether to give this example; seeing that it has personal implications. But it affords so clear an insight into Mr. Mill's character, and shows so much more vividly than any description could do how fine were the motives swaying his conduct, that I think the occasion justifies disclosure of it.

Some seven years ago, after bearing as long as was possible the continued losses entailed on me by the publication of the "System of Philosophy," I notified to the subscribers that I should be obliged to cease at the close of the volume then in progress. Shortly after the issue of this announcement, I received from Mr. Mill a letter, in which, after expressions of regret, and after naming a plan which he wished to prosecute for reimbursing me, he went on to say: "In the next place . . . . what I propose is, that you should write the next of your treatises, and that I should guarantee the publisher against loss, i. e., should engage, after such length of time as may be agreed on, to make good any deficiency that may occur, not exceeding a given sum, that sum being such as the publisher may think sufficient to secure him." Now, though these arrangements were of kinds that I could not bring myself to yield to, they none the less profoundly impressed me with

Mr. Mill's nobility of feeling, and his anxiety to further what he regarded as a beneficial end. Such proposals would have been remarkable even had there been entire agreement of opinion. But they were the more remarkable as being made by him under the consciousness that there existed between us certain fundamental differences, openly avowed. I had, both directly and by implication, combated that form of the experiential theory of human knowledge which characterizes Mr. Mill's philosophy; in upholding Realism, I had opposed, in decided ways, those metaphysical systems to which his own Idealism was closely allied; and we had long carried on a controversy respecting the test of truth, in which I had similarly attacked Mr. Mill's positions in an outspoken manner. That under such circumstances he should have volunteered his aid, and urged it upon me, as he did, on the ground that it would not imply any personal obligation, proved in him a very exceptional generosity.

Quite recently I have seen afresh illustrated this fine trait—this ability to bear with unruffled temper and without any diminution of kindly feeling the publicly-expressed antagonism of a friend. The last evening I spent at his house was in the company of another invited guest, who, originally agreeing with him entirely on certain disputed questions, had some fortnight previously displayed his change of view—nay, had publicly criticised some of Mr. Mill's positions in a very undisguised manner. Evidently, along with his own unswerving allegiance to truth, there was in Mr. Mill an unusual power of appreciating in others a like conscientiousness; and so of suppressing any feeling of irritation produced by difference—suppressing it not in appearance only, but in reality; and that, too, under the most trying circumstances.

I should say, indeed, that Mr. Mill's general characteristic, emotionally considered, was an unusual predominance of the higher sentiments—a predominance which tended, perhaps, both in theory and practice, to subordinate the lower nature unduly. That rapid advance of age which has been conspicuous for some years past, and which doubtless prepared the way for his somewhat premature death, may, I think, be regarded as the outcome of a theory of life which made learning and working the occupations too exclusively considered. But, when we ask to what ends he acted out this theory, and in so doing too little regarded his bodily welfare, we see that even here the excess, if such we call it, was a noble one. Extreme desire to further human welfare was that to which he sacrificed himself.

HIS BOTANICAL STUDIES.

BY HENRY TRIMEN.

If we would have a just idea of any man's character, we should view it from as many points and under as many aspects as we can. The side-lights thrown by the lesser occupations of a life are often very strong, and bring out its less obvious parts into startling prominence. Much especially is to be learned of character by taking into consideration the employment of times of leisure or relaxation, the occupation of such hours being due almost solely to the natural bent of the individual, without the interfering action of necessity or expediency. Most men, perhaps especially eminent men, have a "hobby," some absorbing object, the pursuit of which forms the most natural avocation of their mind, and to which they turn with the certainty of at least satisfaction, if not of exquisite pleasure. The man who follows any branch of natural science in this way is almost always especially happy in its prosecution, and his mental powers are refreshed and invigorated for the more serious and engrossing, if less congenial, occupation of his life. Mr. Mill's hobby was practical field botany; surely in all ways one very well suited to him.

Of the tens of thousands who are acquainted with the philosophical writings of Mr. Mill, there are probably few beyond the circle of his personal friends who are aware that he was also an author in a modest way on botanical subjects, and a keen searcher after wild plants. His short communications on botany were chiefly, if not entirely, published in a monthly magazine called the *Phytologist*, edited from its commencement in 1841 by the late George Luxford till his death in 1854, and afterward conducted by Mr. A. Irvine, of Chelsea, an intimate friend of Mr. Mill's, till its discontinuance in 1863. In the early numbers of this periodical especially will be found frequent notes and short papers on the facts of plant-distribution brought to light by Mr. Mill during his botanical rambles. His excursions were chiefly in the county of Surrey, and especially in the neighborhood of Guildford and the beautiful vale of the Sittingbourne, where he had the satisfaction of being the first to notice several plants of interest, as *Polygonum dumetorum*, *Isatis tinctoria*, and *Impatiens fulva*, an American species of balsam, affording a very remarkable example of complete naturalization in the Wey and other streams connected with the lower course of the Thames. Mr. Mill says he first observed this interloper in 1822, at Albury, a date which probably marks about the commencement of his botanical investigations, if not that of the first notice of the plant in this country. Mr. Mill's copious MS. lists of observations in Surrey were subsequently forwarded to the late Mr. Salmon of Godalming, and have been since published with the large collection of facts made by that botanist in the "Flora of Surrey," printed under the auspices of the Holmesdale (Reigate) Natural History Club. Mr. Mill also contributed to the same scientific magazine some short notes on Hampshire botany, and is believed to have helped in the compilation of Mr. G. G. Mill's "Catalogue of the Plants of Great Marlow, Bucks."

During his frequent and latterly prolonged residence at Avignon, Mr. Mill, carrying on his botanical observations, had become very well acquainted with the vegetation of the district, and, at the time of his death, had collected a mass of notes and observations on the subject. It is believed to have been his intention to have printed these as the foundation of a flora of Avignon.

In the slight contributions to the literature of botany made by Mr. Mill, there is nothing which gives any inkling of the great intellectual powers of their writer. Though always clear and accurate, they are merely such notes as any working botanical collector is able to supply in abundance. Mainly content with the pursuit as an out-door occupation, with such an amount of home-work as was necessary to determine the names and affinities of the species, Mr. Mill never penetrated deeply into the philosophy of botany, so as to take rank among those who have, like Herbert Spencer, advanced that science by original work either of experience or generalization, or have entered into the battle-field where the great biological questions of the day are being fought over. The writer of this notice well remembers meeting, a few years since, the (at that time) parliamentary logician, with his trousers turned up out of the mud, and armed with the tin insignia of his craft, busily occupied in the search after a marsh-loving rarity in a typical spongy wood on the clay to the north of London.

But, however followed, the investigation of Nature cannot fail to influence the mind in the direction of a more just appreciation of the necessity of system in arrangement, and of the principles which must regulate all attempts to express notions of system in a classification. Traces of this are not difficult to find in Mr. Mill's writings. It may be safely stated that the chapters on classification in the "Logic" would not have taken the form they have had not the writer been a naturalist as well as a logician. The views expressed so clearly in these chapters are chiefly founded on the actual needs experienced by the systematic botanist, and the argument is largely sustained by references to botanical systems and arrangements. Most botanists agree with Mr. Mill in his objections to Dr. Whewell's views of a natural classification by resemblance to "types" instead of in accordance with well-selected characters; and, indeed, the whole of these chapters are well deserving the careful study of naturalists, notwithstanding that the wonderfully rapid progress in recent years of new ideas, lying at the very root of all the natural sciences, may be thought by some to give the whole argument, in spite of its logical excellence, a somewhat antiquated flavor.

HIS PLACE AS A CRITIC.

BY W. MINTO.

It was in his earlier life, when his enthusiasm for knowledge was fresh, and his active mind, "all as hungry as the sea," was reaching out eagerly and strenuously to all sorts of food for thought, literary, philosophical, and political, that Mr. Mill set himself, among other things, to study and theorize upon poetry and the arts generally. He could hardly have failed to know the most recent efflorescence of English poetry, living as he did in circles where the varied merits of the new poets were largely and keenly discussed. He had lived also for some time in France, and was widely read in French poetry. He had never passed through the ordinary course of Greek and Latin at school and college, but he had been taught by his father to read these languages, and had been accustomed from the first to regard their literature as literature, and to read their poetry as poetry. These were probably the main elements of his knowledge of poetry. But it was not his way to dream or otherwise luxuriate over his favorite poets for pure enjoyment. Mr. Mill was not a cultivator of art for art's sake. His was too fervid and militant a soul to lose itself in serene love and culture of the calmly beautiful. He read poetry for the most part with earnest, critical eye, striving to account for it, to connect it with the tendencies of the age; or he read to find sympathy with his own aspirations after heroic energy. He read De Vigny and other French poets of his generation with an eye to their relations to the convulsed and struggling state of France, and because they were compelled by their surroundings to take life *au sérieux*, and to pursue with all the resources of their art something different from beauty in the abstract. Luxurious passive enjoyment or torpid half-enjoyment must have been a comparatively rare condition of his finely-strung, excitable, and fervid system. I believe that his moral earnestness was too imperious to permit much of this. He was capable, indeed, of the most passionate admiration of beauty, but even that feeling seems to have been interpenetrated by a certain militant apostolic fervor; his love was as the love of a religious soldier for a patron saint, who extends her aid and countenance to him in his wars. I do not mean to say that his mind was in a perpetual glow; I mean only that this surrender to his impassioned transports was more characteristic of the man than serene openness to influx of enjoyment. His "Thoughts on Poetry and its Varieties," while clear and strenuous as most of his thoughts were, are neither scientifically precise, nor do they contain any notable new idea not previously expressed by Coleridge—except, perhaps, the idea that emotions are the main links of association in the poetic mind; still, his working out of the definition of poetry, his distinction between novels and poems, and between poetry and eloquence, is interesting as throwing light upon his own poetic susceptibilities. He holds that poetry is the "delineation of the deeper and more secret workings of human emotion." It is curious to find one, who is sometimes assailed as the advocate of a grovelling philosophy, complaining that the chivalrous spirit has almost disappeared from books of education, that the youth of both sexes of the educated classes are growing up unromantic. "Catechisms," he says, "will be found a poor substitute for the old romances, whether of chivalry or faëry, which, if they did not give a true picture of actual life, did not give a false one, since they did not profess to give any, but (what was much better) filled the youthful imagination with pictures of heroic men, and of what are at least as much wanted—heroic women."

If it is asked why Mr. Mill, with all his width of knowledge and sympathy, has achieved so little of a reputation as a miscellaneous writer, part of the reason no doubt is, that he sternly repressed his desultory tendencies and devoted his powers to special branches of knowledge, attaining in them a distinction that obscured his other writings. Another reason is, that, although his style is extremely clear, he was for popular purposes dangerously familiar with terms belonging more or less to the schools. He employed these in literary generalizations, without remembering that they were not equally familiar to his readers; and thus general readers, like Tom Moore, or the author of the recent notice in the *Times*, who read more for amusement than instruction, were disposed to consider Mr. Mill's style "vastly unreadable."

HIS WORK IN PHILOSOPHY.

BY J. H. LEVY.

To a savage contemplating a railway-train in motion, the engine would present itself as the master of the situation—the determining cause of the motion and direction of the train. It visibly takes the lead, it looks big and important, and it makes a great noise. Even people a long way up in the scale of civilization are in the habit of taking these attributes, perhaps not as the essential ones of leadership, but at all events as those by which a leader may be recognized. Still, that blustering machine, which puffs and snorts, and drags a vast multitude in its wake, is moving along a track determined by a man hidden away from the public gaze. A line of rail lies separated from an adjacent one, the pointsman moves a handle, and the foaming giant, that would, it may be, have sped on to his destruction and that of the passive crew who follow in his rear, is shunted to another line, running in a different direction and to a more desirable goal.

The great intellectual pointsman of our age—the man who has done more than any other of this generation to give direction to the thought of his contemporaries—has passed away, and we are left to measure the loss to humanity by the result of his labors. Mr. Mill's achievements in both branches of philosophy are such as to give him the foremost place in either. Whether we regard him as an expounder of the philosophy of mind, or the philosophy of society, he is *facile princeps*. Still it is his work in mental science which will, in our opinion, be in future looked upon as his great contribution to the progress of thought. His work on political economy not only put into thorough repair the structure raised by Adam Smith, Malthus, and Ricardo, but raised it at least one story higher. His inestimable "System of Logic" was a revolution. It hardly needs, of course, to be said that he owed much to his predecessors; that he borrowed from Whewell much of his classification, from Brown the chief lines of his theory of causation, from Sir John Herschel the main principles of the inductive methods. Those who think this a disparagement of his work must have very little conception of the mass of original thought that still remains to Mr. Mill's credit, the great critical power that could gather valuable truths from so many discordant sources, and the wonderful synthetic ability required to weld these and his own contributions into one organic whole.

When Mr. Mill commenced his labors, the only logic recognized was the syllogistic. Reasoning consisted solely, according to the then dominant school, in deducing from general propositions other propositions less general. It was even asserted confidently that nothing more was to be expected—that an inductive logic was impossible. This conception of logical science necessitated some general propositions to start with; and these general propositions being *ex hypothesi* incapable of being proved from other propositions, it followed that, if they were known to us at all, they must be original data of consciousness. Here was a perfect paradise of question-begging. The ultimate major premiss in every argument being assumed, it could, of course, be fashioned according to the particular conclusion it was called in to prove. Thus an "artificial ignorance," as Locke calls it, was produced, which had the effect of sanctifying prejudice by recognizing so-called necessities of thought as the only bases of reasoning. It is true that outside of the logic of the schools great advances had been made in the rules of scientific investigation; but these rules were not only imperfect in themselves, but their connection with the law of causation was but imperfectly realized, and their true relation to syllogism hardly dreamed of.

Mr. Mill altered all this. He demonstrated that the general type of reasoning is neither from generals to particulars, nor from particulars to generals, but from particulars to particulars. "If from our experience of John, Thomas, etc., who once were living but are now dead, we are entitled to conclude that all human beings are mortal, we might surely, without any logical inconsequence, have concluded at once, from those instances, that the Duke of Wellington is mortal. The mortality of John, Thomas, and others is, after all, the whole evidence we have for the mortality of the Duke of Wellington. Not one iota is added to the proof by interpolating a general proposition." We not only may, according to Mr. Mill, reason from some particular instances to others, but we frequently do so. As, however, the instances which are sufficient to prove one fresh instance must be sufficient to prove a general proposition, it is most convenient to at once infer that general proposition which then becomes a formula according to which (but not from which) any number of particular inferences may be made. The work of deduction is the interpretation of these formulæ, and therefore, strictly speaking, is not inferential at all. The real inference was accomplished when the universal proposition was arrived at.

It will easily be seen that this explanation of the deductive process completely turns the tables on the transcendental school. All reasoning is shown to be at bottom inductive. Inductions and their interpretation make up the whole of logic, and to induction accordingly Mr. Mill devoted his chief attention. For the first time induction was treated as the *opus magnum* of logic, and the fundamental principles of science traced to their inductive origin. It was this, taken with his theory of syllogism, which worked the great change. Both his "System of Logic," and his "Examination of Sir William Hamilton's Philosophy," are for the most part devoted to fortifying this position, and demolishing beliefs inconsistent with it. As a systematic psychologist Mr. Mill has not done so much as either Prof. Bain or Mr. Herbert Spencer. The perfection of his method, its application, and the uprooting of prejudices which stood in its way—this was the task to which Mr. Mill applied himself with an ability and success rarely matched and never surpassed.

HIS WORK IN POLITICAL ECONOMY

BY PROF. J. E. CAIRNES.

The task of fairly estimating the value of Mr. Mill's achievements in political economy—and indeed the same remark applies to what he has done in every department of philosophy—is rendered particularly difficult by a circumstance which constitutes their principal merit. The character of his intellectual, no less than of his moral nature, led him to strive to connect his thoughts, whatever was the branch of knowledge at which he labored, with the previously existing body of speculation, to fit them into the same framework, and exhibit them as parts of the same scheme; so that it might be truly said of him that he was at more pains to conceal the originality and independent value of his contributions to the stock of knowledge than most writers are to set forth those qualities in their compositions. As a consequence of this, hasty readers of his works, while recognizing the comprehensiveness of his mind, have sometimes denied its originality; and in political economy in particular he has been frequently represented as little more than an expositor and popularizer of Ricardo. It cannot be denied that there is a show of truth in this representation; about as much as there would be in asserting that Laplace and Herschel were the expositors and popularizers of Newton, or that Faraday performed a like office for Sir Humphrey Davy. In truth, this is an incident of all progressive science. The cultivators in each age may, in a sense, be said to be the interpreters and popularizers of those who have preceded them; and it is in this sense, and in this sense only, that this part can be attributed to Mill. In this respect he is to be strongly contrasted with the great majority of writers on political economy, who, on the strength, perhaps, of a verbal correction, or an unimportant qualification, of a received doctrine, if not on the score of a pure fallacy, would fain persuade us that they have achieved a revolution in economic doctrine, and that the entire science must be rebuilt from its foundation in conformity with their scheme. This sort of thing has done infinite mischief to the progress of economic science; and one of Mill's great merits is that both by example and by precept he steadily discountenanced it. His anxiety to affiliate his own speculations to those of his predecessors is a marked feature in all his philosophical works, and illustrates at once the modesty and comprehensiveness of his mind.

On some points, however, and these points of supreme importance, the contributions of Mill to economic science are very much more than developments—even though we understand that term in its largest sense—of any previous writer. No one can have studied political economy in the works of its earlier cultivators without being struck with the dreariness of the outlook which, in the main, it discloses for the human race. It seems to have been Ricardo's deliberate opinion that a substantial improvement in the condition of the mass of mankind was impossible. He considered it as the normal state of things that wages should be at the *minimum* requisite to support the laborer in physical health and strength, and to enable him to bring up a family large enough to supply the wants of the labor-market. A temporary improvement, indeed, as the consequence of expanding commerce and growing capital, he saw that there might be; but he held that the force of the principle of population was always powerful enough so to augment the supply of labor as to bring wages ever again down to the *minimum* point. So completely had this belief become a fixed idea in Ricardo's mind, that he confidently drew from it the consequence that in no case could taxation fall on the laborer, since—living, as a normal state of things, on the lowest possible stipend adequate to maintain him and his family—he would inevitably, he argued, transfer the burden to his employer, and a tax, nominally on wages, would, in the result, become invariably a tax upon profits. On this point Mill's doctrine leads to conclusions directly opposed to Ricardo's, and to those of most preceding economists. And it will illustrate his position, as a thinker, in relation to them, if we note how this result was obtained. Mill neither denied the premises nor disputed the logic of Ricardo's argument: he accepted both; and in particular he recognized fully the force of the principle of population; but he took account of a further premiss which Ricardo had overlooked, and which, duly weighed, led to a reversal of Ricardo's conclusion. The *minimum* of wages, even such as it exists in the case of the worst-paid laborer, is not the very least sum that human nature can subsist upon; it is something more than this: in the case of all above the worst-paid class it is decidedly more. The *minimum* is, in truth, not a physical, but a moral *minimum*, and, as such, is capable of being altered with the changes in the moral character of those whom it affects. In a word, each class has a certain standard of comfort below which it will not consent to live, or, at least to multiply—a standard, however, not fixed, but liable to modification with the changing circumstances of society, and which in the case of a progressive community is, in point of fact, constantly rising, as moral and intellectual influences are brought more and more effectually to bear on the masses of the people. This was the new premiss brought by Mill to the elucidation of the wages question, and it sufficed to change the entire aspect of human life regarded from the point of view of Political Economy. The practical deductions made from it were set forth in the celebrated chapter on "The Future of the Industrial Classes"—a chapter which, it is no exaggeration to say, places a gulf between Mill and all who preceded him, and opens an entirely new vista to economic speculation.

The doctrine of the science with which Mill's name has been most prominently associated, within the last few years, is that which relates to the economic nature of land, and the consequences to which this should lead in practical legislation. It is very commonly believed that on this point Mill has started aside from the beaten highway of economic thought, and propounded views wholly at variance with those generally entertained by orthodox economists. No economist need be told that this is an entire mistake. In truth there is no portion of the economic field in which Mill's originality is less conspicuous than in that which deals with the land. His assertion of the peculiar nature of landed property, and again his doctrine as to the "unearned increment" of value arising from land with the growth of society, are simply direct deductions from Ricardo's theory of rent, and cannot be consistently denied by any one who accepts that theory. All that Mill has done here has been to point the application of principles, all but universally accepted, to the practical affairs of life. This is not the place to consider how far the plan proposed by him for this purpose is susceptible of practical realization; but it may at least be confidently stated that the scientific basis on which his proposal rests is no strange novelty invented by him, but simply a principle as fundamental and widely recognized as any within the range of the science of which it forms a part.

There is one more point which ought not to be omitted from even the most meagre summary. Mill was not the first to treat political economy as a science, but he was the first, if not to perceive, at least to enforce the lesson, that, just because it is a science, its conclusions carried with them no obligatory force with reference to human conduct. As a science it tells us that certain modes of action lead to certain results; but it remains for each man to judge of the value of the results thus brought about, and to decide whether or not it is worth while to adopt the means necessary for their attainment. In the writings of the economists who preceded Mill it is very generally assumed that to prove that a certain course of conduct tends to the most rapid increase of wealth suffices to entail upon all who accept the argument the obligation of adopting the course which leads to this result. Mill absolutely repudiated this inference, and, while accepting the theoretic conclusion, held himself perfectly free to adopt in practice whatever course he preferred. It was not for political economy or for any science to say what are the ends most worthy of being pursued by human beings: the task of science is complete when it shows us the means by which the ends may be attained; but it is for each individual man to decide how far the end is desirable at the cost which its attainment involves. In a word, the sciences should be our servants, and not our masters. This was a lesson which Mill was the first to enforce, and by enforcing which he may be said to have emancipated economists from the thraldom of their own teaching. It is in no slight degree, through the constant recognition of its truth, that he has been enabled to divest of repulsiveness even the most abstract speculations, and to impart a glow of human interest to all that he has touched.

HIS INFLUENCE AT THE UNIVERSITIES.

BY PROF. FAWCETT.

Some time ago, when there was no reason to suppose that we should so soon have to mourn the loss of the great thinker and of the kind friend who has just passed away, I had occasion to remark upon the influence which Mr. Mill had exercised at the universities. I will quote my words as they stand, because it is difficult to write with impartiality about one whose recent death we are deploring; and Mr. Mill would, I am sure, have been the first to say that it is certainly not honoring the memory of one who is dead to lavish upon him praise which would not be bestowed upon him if he were living. I will, therefore, repeat my words exactly as they were written two years since: "Any one who has resided during the last twenty years at either of our universities must have noticed that Mr. Mill is the author who has most powerfully influenced nearly all the young men of the greatest promise." In thus referring to the powerful influence exercised by Mr. Mill's works, I do not wish it to be supposed that this influence is to be measured by the extent to which his books form a part of the university *curriculum*. His "Logic" has no doubt become a standard examination-book at Oxford. At Cambridge, the Mathematical and Classical Triposes still retain their former *prestige*. The moral science tripos, though increasing in importance, still attracts a comparatively small number of students, and there is probably no other examination for which it is necessary to read Mr. Mill's "Logic" and "Political Economy." This fact affords the most satisfactory evidence that the influence he has exerted is spontaneous, and is therefore likely to be lasting in its effects. If students had been driven to read his books by the necessity which examinations impose, it is quite possible that, after the examination, the books might never be looked at again. A resident, however, at the university can scarcely fail to be struck with the fact that many who perfectly well know that they will never in any examination be asked to answer a question in logic or political economy, are among the most diligent students of Mr. Mill's books. When I was an undergraduate I well remember that most of my friends who were likely to take high mathematical honors were already so intimately acquainted with Mr. Mill's writings, and were so much imbued with their spirit, that they might have been regarded as his disciples. Many looked up to him as their teacher; many have since felt that he then instilled into them principles which, to a great extent, have guided their conduct in after-life. Any one who is intimately acquainted with Mr. Mill's writings will readily understand how it is that they possess such peculiar attractiveness for the class of readers to whom I am now referring. There is nothing more characteristic in his writings than generosity and courage. He always states his opponent's case with the most judicial impartiality; he never shrinks from the expression of opinion because he thinks it unpopular, and there is nothing so abhorrent to him as that bigotry which prevents a man from appreciating what is just and true in the views of those who differ from him. This toleration, which is so predominant a feature of his writings, is probably one of the rarest of all qualities in a controversialist. Those who do not possess it always produce an impression that they are unfair; and this impression, once produced, exercises a repelling influence upon the young.

To those who believe that the influence Mr. Mill has exercised at the universities has been in the highest degree beneficial—to those who think that his books not only afford the most admirable intellectual training, but also are calculated to produce a most healthy moral influence—it may be some consolation, now that we are deploring his death, to know that, although he has passed away, he may still continue to be a teacher and a guide. I believe he never visited the English universities; it was consequently entirely through his books that he was known. Not one of those who were his greatest admirers at Cambridge, when I was an undergraduate, ever saw him till many years after they had left the university. Nothing, perhaps, was so remarkable in his character as his tenderness to the feelings of others, and the deference with which he listened to those in every respect inferior to himself. There never was a man who was more entirely free from that intellectual conceit which breeds disdain. Nothing is so discouraging and heart-breaking to young people as the sneer of an intellectual cynic. A sarcasm about an act of youthful mental enthusiasm not only often casts a fatal chill over the character, but is resented as an injury never to be forgiven. The most humble youth would have found in Mr. Mill the warmest and most kindly sympathy.

HIS POSITION AS A PHILOSOPHER.

BY W. A. HUNTER.

It is always hazardous to forecast the estimation in which any man will be held by posterity. In one sense truly we have no right to anticipate the judgment of the future, sufficient for us to form opinions satisfactory within the limits of our own generation. Sometimes, by evil chance, a great name is covered with undeserved reproach, and it is reserved for a distant future to do it justice. But, such a work as Mr. Carlyle did for Cromwell we may confidently anticipate will never be required for the name of John Stuart Mill. He is already enrolled among the first of contemporary thinkers, and from that list his name will never be erased. The nature of Mr. Mill's work is such as to make it easy to predict the character of his future reputation. His is the kind of philosophy that is destined to become the commonplace of the future. We may anticipate that many of his most remarkable views will become obsolete in the best sense, they will become worked up into practice, and embodied in institutions. Indeed, the place that he will hold, will probably be closely resembling that of the great father of English philosophy, John Locke. There is, indeed, amid distinguishing differences, a remarkable similarity between the two men, and the character of their influence on the world. What Locke was to the liberal movements of the seventeenth century, Mr. Mill has more than been to the liberal movement of the nineteenth century. The intellectual powers of the two men had much in common, and they were exercised upon precisely similar subjects. The "Essay on the Human Understanding" covered doubtless a field more purely psychological than the "Logic," but we must remember that the "Analysis of the Mind" by the elder Mill had recently carried the inductive study of mind to an advanced point. If, however, we regard less the topics on which these two illustrious men wrote, than the special service rendered by each of them to intellectual progress, we may not unfittingly compare the work of Locke—the descent from metaphysics to psychology—to the noble purpose of redeeming logic from the superstition of the Aristotelians, and exalting it to something higher than a mere verbal exercise for school-boys. The attack that Locke opened with such tremendous effect on the *a priori* school of philosophy was never more ably supported than by the "Logic" and controversial writings of Mr. Mill.

The remarkable fact in regard to both these great thinkers—these conquerors in the realms of abstract speculation—is their relation to politics. Locke was the political philosopher of the Revolution of 1688; Mr. Mill has been the political philosopher of the democracy of the nineteenth century. The vast space that lies between their treatises represents a difference, not in the men, but in the times. Locke found opposed to the common weal an odious theory of arbitrary and absolute power. It is interesting to remember what were the giants necessary to be slain in those days. The titles of his first chapters on "Government" significantly attest the rudimentary condition of political philosophy in Locke's day. Adam was generally considered to have had a divine power of government, which was transmitted to a favored few of his descendants. Accordingly, Locke disposes of Adam's title to sovereignty, to whatever origin it may have been ascribed—to "creation," "donation," "the subjection of Eve," or "fatherhood." There is something almost ludicrous in discussing fundamental questions of government with reference to such Scriptural topics; and it is a striking evidence of the change that has passed over England since the Revolution, that, whereas Locke's argument looks like a commentary on the Bible, even the bishops now do not in Parliament quote the Bible on the question of marriage with a deceased wife's sister. Nevertheless, Locke clearly propounded the great principle which, in spite of many errors and much selfishness, has been the fruitful heritage of the Whig party. "Political power, then, I take to be a right of making laws with penalties of death, and consequently all less penalties, for the regulating and preserving of property and of employing the force of the community in the execution of such laws, and in the defence of the commonwealth from foreign injury, *and all this only for the public good.*" Locke also enounced the maxim that the state of Nature is one of equality. Mr. Mill's special views on the land-question are not without parallel in Locke, for that acute thinker distinctly laid down that "labor" was the true ground even of property in land. Still it must be confessed that Locke's political philosophy is much cruder than Mr. Mill's. His "Essay on Government" is as the rough work of a boy of genius, the "Representative Government" a finished work of art of the experienced master. And this difference corresponds with the rate of political progress. The English constitution, as we now understand it, was unknown at the Revolution; it had to be slowly created; now the great task of the future is to raise the mass of the people to a higher standard of political intelligence and material comfort. To that great end no man has contributed so much as Mr. Mill.

Perhaps, the one writing for which above all others Mr. Mill's disciples will love his memory, is his essay "On Liberty." In this undertaking Mr. Mill followed the noble precedent of Locke, with greater largeness of view, and perfection of work. Locke's four letters "Concerning Toleration" constitute a splendid manifesto of the Liberals of the seventeenth century. The principle that the ends of political society are life, health, liberty, and immunity from harm, and not the salvation of souls, has taken nearly two centuries to root itself in

English law, but has long been recognized by all but the shallowest bigots. And yet Locke spoke of "atheism being a crime, which, for its madness as well as guilt, ought to shut a man out of all sober and civil society." Here, again, what a stride does the *Liberty* make? It is, once more, the difference of the times, rather than of the men. The same noble and prescient insight into the springs of national greatness and social progress characterizes the work of both men, but in what different measures! Again, we must say, the disciple is greater than the master. Closely bearing on this topic, is the relation of the two men to Christianity. Locke not only wrote to show the "Reasonableness of Christianity," but paraphrased several of the books of the New Testament. Mr. Mill has never written one sentence to give the least encouragement to Christianity. But, although a contrast appears to exist, there is really none. Locke was what may be called a Bible Christian. He rejected all theological systems, and constructed his religious belief in the truly Protestant way, with the Bible and his inner consciousness. His creed was the Bible as conformed to reason; but he never doubted which, in the event of a conflict, ought to give way. To him the destructive criticism of biblical scholars, and the discoveries of geology, had given no disquietude; and he died with the happy conviction that, without abandoning his religious teaching, he could remain faithful to Reason. Mr. Mill inherited a vast controversy; and he had to make a choice: like Locke, he remained faithful only to Reason.

Perhaps, it might be urged, this comparison leaves out of account the very greatest work of Mr. Mill—his "Political Economy." Locke lived too soon to be an Adam Smith; but, curiously enough, the parallel is not broken even at this point. In 1691, and again in 1695, he wrote: "Some considerations of the consequences of the lowering of interest, and raising the value of money," in which he propounded, among other views, that "taxes, however contrived, and out of whose hands soever immediately taken, do, in a country where the great fund is in land, for the most part terminate upon land." There is of course no comparison between the two men on this head; nevertheless it is interesting to note in prototype the germs of the great work of Mr. Mill. It shows the remarkable, and by no means accidental, similarity between the men.

This parallel is already too much drawn out; otherwise it would be worth observing on the characters and lives of these two men. Enough, however, has been said to show that we may not unreasonably anticipate for Mr. Mill a future such as has fallen to Locke. His wisdom will be the commonplace of other times; his theories will be realized in political institutions; and we may hope and believe the working-class will rise to such a standard of wealth, and culture, and political power, as to realize the generous aspirations of one of England's greatest sons.

EDITOR'S TABLE.

GEOGRAPHY IN SCHOOLS.

WHILE there is great ado about methods in teaching this subject, and the "battle of the geographies" waxes fierce before the school boards, but few stop to inquire into the real claims of the study, and he who should venture to say that it has no business in schools at all, that it usurps time which had better be given to other things, and is of very low value as a means of mental cultivation, would be regarded as absurd. Yet such an idea is entertained by many thoughtful persons, and it increases in force as our educational system is more closely scrutinized.

In his celebrated inaugural address, at the University of St. Andrews, Mr. J. S. Mill remarked: "It has always seemed to me a great absurdity that history and geography should be taught in schools; except in elementary schools for children of the laboring-classes, whose subsequent access to books is limited. Who ever really learned history and geography except by private reading? and, what an utter failure a system of education must be, if it has not given the pupil a sufficient taste for reading, to seek for himself those most attractive and easily intelligible of all kinds of knowledge! Besides, such history and geography as can be taught in schools, exercise none of the faculties of intelligence, except memory."

If this very decisive verdict be thought merely the opinion of a theorist, it is easy to reënforce it by the judgment of practical men who speak from experience in the management of schools. A committee on "Text-books, and a Graded Course of Instruction," of the public schools of Milwaukee, in their report to the board of School Commissioners on the study of geography, say: "The committee have given the subject full and careful consideration, and have come to the conclusion that the study of geography, as now pursued in our schools, should be radically changed. Considering the time devoted to it, and the application required, we are of the opinion that no study is productive of results so meagre and unsatisfactory. It will not be contended that much is to be gained in the way of mental discipline from geography as taught in this city, and we might as well say generally throughout this country. The same amount of time and labor, bestowed upon many other branches of knowledge, would do a great deal more for development of the faculties of the mind. About the only positive result obtained is, storing the memory with an array of disconnected facts, which may indeed be made available in astonishing visitors at examinations, but are utterly useless as a means of unfolding the thinking powers. Nay, more, the very object of the study is defeated by the methods of instruction commonly in use. It is possible to find whole classes of pupils who have spent several years in 'learning geography,' and who can answer endless columns of questions in locating places; but who can in no sense be said to have acquired the knowledge which geography—rightly understood—is intended to impart."

They remark further: "The committee are of opinion that altogether *too much time* is devoted to geography in our schools. It seems to us that a sufficient knowledge of the subject might be acquired by considerably abridging the number of lessons, and giving the time to studies of at least equal importance, which are now sacrificed to make room for the geography recitations. A competent knowledge of our own language is surely one of the leading objects of the most common education. We are of opinion that our course of instruction in the English language is altogether too limited in its scope and imperfect in its methods. This should include something more than reading, spelling, grammar, and an occasional composition. The language, in its elements and structure, should be taught on scientific principles, so far as they have been ascertained, and the power to use it in speaking and writing, not only correctly but elegantly, systematically *developed* from the lowest to the highest grade. Then, again, no course of instruction—however elementary—can in our day be said to be complete, which does not aim to cultivate some acquaintance with the leading outlines of natural science; and we are persuaded that, in the more advanced grades at least, a portion of the time at present given to geography might be advantageously devoted to giving instruction in botany, zoology, physics, and astronomy, by oral lessons of a simple and elementary nature."

Mr. Mill says that geography exercises none of the powers of intelligence, except the memory, and the committee declare that it does this badly; and both, we think, are right. Loading the memory with an array of arbitrary and disconnected facts is not the proper method of cultivating it. The true office of this faculty is, to be the servant of the other faculties. It is the power which recovers for present use the mind's past acquisitions. But the power of recalling past impressions rests upon the law of association, and rational memory depends upon the relations subsisting among the mental impressions. If knowledge has been digested, and the relations among its objects seen, their recovery in thought is easy and natural; but, where the other faculties are neglected, the memory is merely burdened with arbitrary statements, and only those things are remembered that are burnt into it by interminable repetition. Dr. Arnold reprobates the ordinary school-method of treating geography, and commends the point of view here indicated. He says: "And this deeper knowledge becomes far easier to remember. For my own part, I find it extremely difficult to remember the positions of towns, when I have no other association with them than their situations relatively to each other. But let me once understand the real geography of a country—its organic structure, if I may so call it; the outline of its skeleton, that is, of its hills; the magnitude and course of its veins and arteries, that is, of its streams and rivers; let me conceive of it as a whole made up of connected parts; and then the positions of towns, viewed in reference to these parts, become at once easily remembered, and lively and intelligible besides."

The objection to teaching geography to the young is, that its entire subject matter is beyond the sphere of experience; it is, therefore, much less fit to be used as a means of mental cultivation than many other subjects. Geography deals with an order of ideas which it is extremely difficult for the adult mind to grasp in their true relations, and impossible for the minds of children. "Geography is a description of the earth," and, to begin with, the earth is "a vast globe, or ball." Now, a child may have a correct conception of a ball, which it gets from experience, but it has no conception from experience which will help it to a true idea of what is meant by "25,000 miles in circumference." The notion is utterly beyond its grasp, and, so far from KNOWING the fact, or forming any just mental view of it, it is merely cheated with words. And so it is with the attempt to conceive the extent and relations of the great continental and oceanic tracts of the globe, or of its minor subdivisions into zones and countries, or of its great mountain and river systems. Into all these phenomena there enter an element of vastness, a magnitude of relations, and a scale of diversities, which are little more to the childish mind than if they were described to it in a language not understood. Maps, of course, are helpful, but they are only symbols which the pupil is incompetent to translate into reality. It matters nothing that all the statements of geography may be true; they are true to the pupil only as verbal statements made on authority. All that it can do is to memorize words of description, which is the lowest and most worthless work of education. An English gentleman, who was once riding on horseback in the country, was accosted by a boy, who offered, for a penny, to tell him all the capitals of Europe. When he had done, the gentleman replied, "Here is your penny, and I will give you another if you will tell me whether they are animals or vegetables." "Animals," replied the boy, promptly. This is, no doubt, an extreme case; but it illustrates what is very generally true in the school-study of geography—that the pupils have no adequate ideas of what the words mean.

The difficulty with geography is, that it does not rouse children to think, and cannot furnish them with materials for the exercise of reason and judgment, because, for this purpose, the things reasoned about require to be immediately accessible to thought. Without going so far as Mr. Mill, who declares geography in schools to be an absurdity, we are profoundly convinced that the current teaching of it to young pupils *is* absurd. It should be postponed to the later stages of study, when the mind has attained a considerable degree of maturity, and then, by means of globes, a general conception of the great features of the earth may be acquired. This will form a suitable preparation for that subsequent reading upon the subject which Mr. Mill suggests.

SCIENTIFIC EDUCATION IN THE FAR WEST.

We spoke, in the June number of The Popular Science Monthly, of the advantages that would arise from connecting the scientific exploration of the several States with their higher educational institutions. We have been since reminded that this is an accomplished fact in at least one of the States, and we hasten to give credit to Minnesota for having taken this new departure in scientific education. It is one of the youngest States in the Union, and a generation ago was but a land of savages, an indefinite tract in the great "Northwest Territory" beyond "Ouisconsin," beyond the distant Mississippi, that we now see taking the lead of the older States in organizing the new education by devoting her university to the comprehensive and practical study of Nature. This step has been but recently taken, and its benefits are prospective; but, if thoroughly carried out, there can be but little question of the advantages that must arise to the people of the State. By a law of 1872, to provide for the geological and natural-history survey of the State, the Board of Regents of the University of Minnesota were charged with the duty of organizing the work, and the Professors of Geology, Chemistry, Botany, and Zoology, of that institution, are the chief officers in carrying on the investigations in these departments, while money appropriations and land-grants are liberally voted to sustain the work, which is broadly laid out and clearly defined.

There is to be "a complete account of the mineral kingdom as represented in the State, including the number, order, dip, and magnitude, of the several geological strata, their richness in ores, coals, clays, peats, salines, and mineral waters, marls, cements, building-stones, and other useful materials, the value of said substances for economical purposes and their accessibility; also an accurate chemical analysis of the various rocks, soils, ores, clays, peats, marls, and other mineral substances, of which complete and exact records shall be made."

The natural-history survey will "include, first, an examination of the vegetable productions of the State, embracing all trees, shrubs, herbs, and grasses, native or naturalized in the State; second, a complete and scientific account of the animal kingdom as properly represented in the State, including all mammalia, fishes, reptiles, birds, and insects."

There is also to be a meteorological investigation of the climate of the State, barometrical and thermometrical observations and measurements of elevations and depressions of the land, with a view to the formation of an authentic map.

It will be a part of the work to collect specimens of "all rocks, soils, ores, coals, fossils, cements, building-stones, plants, woods, skins, and skeletons, of animals, birds, insects, and fishes, and other mineral, vegetable, and animal substances and organisms discovered or examined in the course of said surveys, to be preserved for public inspection, free of cost, in the University of Minnesota, in rooms convenient of access and properly warmed, lighted, ventilated, and furnished, and in charge of a proper scientific curator; and they shall also, whenever the same may be practicable, cause duplicates, in reasonable numbers and quantities, of the above-named specimens to be collected and preserved for the purpose of exchanges with other State universities and scientific institutions."

The movement in this case, it is evident, has been initiated mainly in the interest of the geological survey, but it is to be hoped that the larger objects of education to which it is a means will not be lost sight of. The university will undoubtedly be benefited by taking the responsibility of the work, but the movement will fall greatly short of the good it might accomplish if it is not vitally connected with the educational system of the State. In the cities of Minnesota are growing up numerous normal schools and high-schools, which have a right to share in the general benefits of the undertaking. The specimens obtained by the several departments of the survey are to be collected in the University Museum at St. Anthony, and we are told that duplicates will be exchanged with other State universities and with scientific societies. But should not the claims of the people of the State be considered first, and should not the local schools be furnished with materials for cabinets representing the resources of their own State, and be encouraged to contribute something toward the general object by observations and collections in their own districts? We should be glad to see this element incorporated in the Minnesota experiment.

LITERARY NOTICES.

International Scientific Series, No. III. On Foods. By Edward Smith, M. D., F. R. S. D. Appleton & Co.

A good, popular book on foods has long been wanted, and, as the object of the *International Scientific Series* is to furnish valuable and instructive reading for the general public, this subject was early provided for by securing the best authority in England to treat it. Dr. Smith is well and widely known by his extensive course of physiological experiments on the influence of foods and alcoholic liquors upon the human system, published in the "Philosophical Transactions" in 1859; by his official work as government inspector of practical dietaries for hospitals and almshouses; and by his various publications upon the subject of food and diet. A new work was, however, required, that should give the latest scientific information respecting foods, so clearly and simply written as to be understood by common people, and that should combine fulness of statement with compactness of form and a moderate price. Dr. Smith has realized these difficult conditions in a very remarkable degree in the volume now prepared. Adopting a classification that is recommended by its simplicity, he goes over the whole field and describes the properties, composition, preparations, and adaptations of all the alimentary substances now employed by civilized man. In his preface, the author remarks: "Largely-increased commercial intercourse with distant countries, associated with a marked improvement in the purchasing power of the masses of the people, and the rapid increase of wealth generally, have attracted public attention to the subject of foods and dietaries in an unusual degree, so that not only is there a greater importation of foreign productions than formerly, but new foods, or preparations of foods, are produced almost daily, some of which are specially fitted for certain classes of persons, as children, while others are of general use. Hence our food-supplies, whether natural or prepared, offer increased variety of flavor, if not of nutritive qualities, and foods which were formerly restricted to the few are now commonly found on the tables of the many.

"Scientific research in every civilized nation has also diligently busied itself in the elucidation of the subject, and our knowledge has been increased in reference to the chemical composition, preparation, and physiological effects of food.

"With so many causes of change since the issue of my work on 'Practical Dietary,' it seemed desirable to produce another which should embrace all the generally known and some less known foods, and contain the latest scientific knowledge respecting them, while at the same time the subject should be treated in a popular manner.

"It was originally intended to include both foods and diets in one work, but the subject has now become so large that it was found necessary to limit the present volume to foods alone, and to reserve the subject of diets and dietaries for a future occasion."

The amount of information that Dr. Smith has contrived to compress into this little volnme is quite surprising; it seems, indeed, to have the completeness of a regular cyclopædia of the subject. Besides giving the pith of what is known of the whole range of aliments proper, simple and compound, he includes those outlying groups of bodies which, whether or not they be properly foods, are habitually taken into the system, and have great physiological importance. The properties of water, of air, of wines and spirituous liquors, are well summed up in their relations to the living organism. The volume contains many illustrations and valuable tables, with full-page diagrams, representing graphically the effects of various alimentary agents upon the system in different times and circumstances. Dr. Smith's work will be a standard manual upon the important subject of foods.

Theoretical Navigation and Nautical Astronomy. By Lewis Clark, Lieutenant-Commander U. S. N. New York: D. Van Nostrand, 1872.

This is a book written, as the introduction informs us, "for use at the United States Naval Academy." It is, then, intended to be used by young pupils as a first book, and must be judged by the rules which apply to the ordinary text-book: that is to say, it must be, before all things, clear, eminently accurate, and it must be calculated to develop in the student a habit of exactness; and, since it is a text-book of so practical a subject as navigation, it must be a book of reference which the graduated midshipman can safely use. These are the tests which any one, who writes a book on navigation and nautical astronomy, must attempt to satisfy, and which, it seems, should be easily satisfied, since the subject is an old one, and since such a writer has many works of able predecessors to consult.

These conditions this volume in no wise fulfils. Indeed, its author tells us, in the early portions of his book, that, in the work of interpolating from the "Nautical Almanac," formulæ have been given to meet each particular case. The author has found that, in general, they are of no practical assistance to the student, and even in some cases [are] confusing."

How an interpolation is to be made unless by the aid of a formula, the author does not tell us, although the mind naturally is anxious upon so important a point.

He goes on to add a practical precept, however, to the effect that he desires to impress upon the student the importance of obtaining the Greenwich time "almost invariably" before consulting the "Almanac." As the "Nautical Almanac" is so constructed that no element can be taken from it *without* a knowledge of the Greenwich time, it seems almost a work of supererogation to "impress" this fact at the 26th page of a work on navigation.

But, allowing these two practical precepts to stand as examples of the conclusions which the author's experience at sea has led him to, let us briefly notice some of the more important features of the early portions of the treatise, remarking that, to fulfil its purpose as a suitable text-book, these should be exact and clear; and, further, remembering that it is important that the interests of the student should be sedulously guarded, and that his first ideas should be of the most definite nature and *strictly* correct.

Let us remember, too, that a very poor book, of no peculiar importance in itself, has a claim to notice in an educational point of view. There is hardly a middle ground between goodness and badness in such a one: if it be good, let us have it by all means; if bad, it is a duty to warn others against it.

Perhaps there is nothing more important to the navigator than a clear conception of the astronomical ideas of time, latitude, and longitude. "Longitude," says our author, "is the angular distance between any meridian and a fixed or prime meridian. It may be considered as an angle at the pole," etc.

Longitude of what? Any definition of longitude should begin, "*the* longitude of a place is," etc. There is no abstract thing called longitude; but there is a certain definite coördinate for every point on the earth's surface, which is the object of the definition. The same objection applies to the definition of latitude.

On page 18 we learn that "time is the hour-angle of some heavenly body, whose apparent diurnal motion is taken as a measure." Now, there is such a thing as time in the abstract, portions of which we measure, or have measured for us, by certain recurring phenomena.

The explanations of apparent time and of the equation of time are equally faulty; but imagine the surprise of the astronomer, who is told that "astronomical time *commences* at noon, and *is measured toward the westward!*"

From this, to measuring eternity toward the northeast, is but a step. It is evident that, in the author's mind, the words "time" and "day" were equivalent.

With these fundamental errors in the book, it is scarcely probable that it should not be faulty in other ways. And, indeed, it will be found in many points inaccurate, confused, often unintelligible. Perhaps it is hardly necessary to mention certain other faults of the book, which are still discreditable. Many of its demonstrations are taken directly from other text-books, and in no instance, we believe, is a proper acknowledgment made. Its chapter on the Compass is reprinted, almost *verbatim*, from a pamphlet published by the Navy Department on the same subject, and, although the author probably meant to do no injustice, no mention is made of this fact in any way.

On the whole, we must set this down as a harmful book, being full of doubtful statements, of confused mathematics and questionable precepts, and one not likely to improve the art of navigation, or the science of nautical astronomy, in any way.

The Coal-Regions of America: their Topography, Geology, and Development. By James Macfarlane, A. M. 8vo, 679 pages. New York: D. Appleton & Co.

Those who understand how closely our coal-resources are linked to the future prosperity of the nation, and how completely, even now, they are involved with the great elements of manufactures, commerce, and locomotion, will appreciate the value of a comprehensive and fully-illustrated work upon the subject, brought up to the present time. The book aims to be a sort of "encyclopedia of all that is known on the subject that is permanently important and valuable." Government has done a good deal to explore this subject in the several States, but the ponderous volumes of reports they have published are expensive, inaccessible, and require to be digested in the cheap and popular form of a convenient hand-book. For the benefit of those who have but little knowledge in geology, some general information is given on the origin of coal-beds, and their place among the rocky strata, which is applicable to all the coal-regions. Besides the special descriptions of the coal-resources of each State, there is a chapter on the iron-ores of the coal-measures, one on the combustion of coal, and one giving the latest statistics of coal-mines in the United States and in foreign countries. There is also a very valuable chapter on the conditions of success in the coal-trade. The volume is enriched by a contribution from Prof. Newberry on the coal-strata of Ohio, and the author acknowledges important assistance from Profs. Cox, Worthen, White, and Foster. Mr. Macfarlane's work is altogether of a very practical character, and will form an instructive contribution to the literature of the subject.

Liberty, Equality, Fraternity. By James Fitzjames Stephen, Q. C. Holt & Williams.

This is a refreshing book, and is bound to set a good many people thinking. Its contents appeared as a series of anonymous essays in the *Pall Mall Gazette*, and attracted much attention by the forcible manner in which they were written, and the boldness and ability with which they challenged the "liberal tendencies" of English thought. The author takes Mr. Mill as the representative and authoritative expositor of these tendencies, and subjects several of his works to a merciless dissection. Acknowledging his indebtedness to Mr. Mill as the author of the "Logic" and the "Political Economy," he utterly repudiates the doctrines advocated in the "Liberty" and the "Subjection of Woman." The readers of The Popular Science Monthly have had a sample of his method in the article on the "Equality of the Sexes," in the March number, in which he criticised Mr. Mill's main positions upon this subject. In the other essays he takes up the prevailing democratic tendencies as embodied in the phrase "liberty, equality, and fraternity," and deals with them in the same unsparing manner. His book is a plea for social restraints, and a protest against those interpretations of liberty which would make it consist in exemption from restraining agencies. Mr. Stephen exercises the largest liberty of criticism, and writes with the fire of a partisan; but his book abounds with fresh and pregnant suggestions, and its wide circulation will exert a wholesome influence in this country

Caliban: The Missing Link. By Daniel Wilson, LL. D. New York: Macmillan & Co.

This volume is another added to the very considerable list of recent books designed to illustrate the omniscience of Shakespeare. Prof. Wilson thinks that he anticipated the modern doctrine of evolution, and in his character of *Caliban* has delineated the characteristics of the creature Mr. Darwin is in search of, namely, "the missing link between man and beast." The book abounds in extracts from Shakespeare's works, and ingenious interpretations of them, but is vague in its argument, and any thing but satisfactory in its conclusions.

The American Chemist: A Monthly Journal of Theoretical, Analytical, and Technical Chemistry. Edited by Charles F. Chandler, Ph. D., Professor of Analytical and Applied Chemistry in the School of Mines, Columbia College, New York, and Wm. H. Chandler, F. C. S., Professor of Chemistry in the Lehigh University, Bethlehem, Pa. Philadelphia: H. C. Lea.

We have before us vols. i. and ii. (new series) of this valuable monthly, and a careful examination of their contents leads us to recommend it very strongly to public attention. It is edited with skill and judgment, contains a large amount of important information nowhere else so accessible, and deserves a liberal and remunerative patronage. The great science of chemistry, we might almost say, is at the bottom of every thing that is going on in this world. It underlies agriculture; it is the basis of manufactures; it is the key to geology; meteorology depends upon it; it explains domestic processes; is the foundation of physiology and biology, and, moreover, astronomy has lately courted its alliance, and arrived at the most splendid results by its aid. Certainly a magazine which chronicles the progress of this most progressive of the sciences should have a vigorous support, while the reputation of its accomplished editors is the best guarantee of its trustworthy character.

MISCELLANY.

The New Planet Vulcan.—The observation of certain disturbances in the motion of the planet Mercury, and the appearance at particular periods of well-defined circular black spots, passing rapidly across the disk of the sun, have led astronomers to suspect the existence of a ninth planet, interior to Mercury, and with a period of revolution, according to M. Leverrier, of 19.70 days. Such a spot was seen to cross the sun on March 26, 1859, the observer being a French physician named Lescarbault, who thereupon claimed the discovery of the planet, to which the name of Vulcan was assigned. It should be added, however, that other observers had previously witnessed a similar phenomenon. The spot was again seen by Mr. Lummis, of Manchester, on the 20th of March, 1862. From calculations based upon these and other observations, Mr. Hind, of the Twickenham Observatory, England, in a letter last year to the London *Times*, suggested 10 o'clock A. M. on the 24th of March, 1873, as the time when a conjunction of the supposed planet with the sun might be expected to occur. "If the hypothetical body," says Mr. Hind, "is not found upon the sun's disk at that time, it will be, I think, a sufficient proof that my surmises are incorrect." Prof. Kirkwood, in a recent letter to the *Tribune*, states that "Mr. Cowie has just reported the appearance of such a spot on the sun at Shanghai, China, on the morning of March 24, 1873, thus fulfilling the prediction of Mr. Hind, and rendering the existence of such a planet reasonably certain. Prof. Kirkwood's calculations, as given in the letter above quoted, make its sidereal period 34 days, 22 hours, 31 minutes. In a subsequent letter, Prof. Kirkwood calls attention to the fact that similar spots have been observed on the sun, at other dates, which cannot be referred to the same asteroid, and he thence infers the existence of a zone of minor planets within the orbit of Mercury. Why none of these have ever been seen during total eclipses of the sun he explains as follows:

"It is well known that a marked difference obtains between the light-reflecting capacities of the various planets of our system. Mercury, for instance, is in this respect very much inferior to Venus and Jupiter. (*See* Proctor's "Other Worlds than Ours," p. 67.) The difficulty, then, in regard to the invisibility of these asteroids when the sun is eclipsed, may be obviated by supposing their surfaces so constituted as to reflect but a small portion of the sun's light."

Education in Sierra Leone.—Mr. John Pope Hennessy, ex-Governor of Sierra Leone, delivered recently, before the London Society of Arts, an admirable lecture on "the British Settlements in Western Africa." We give a synopsis of that part of the discourse which treated of the state of education. It is the avowed purpose of the British Government to train the natives to habits of self-control, so that they may be finally suffered to govern the country themselves. But that no great progress has been made in the preliminary work of education is admitted on all sides. In 1869, "education was most inadequately provided for" in Sierra Leone. In 1870 the "conspicuous listlessness and inattention of the scholars" are noted by the Director of Public Instruction. In 1872 Mr. Hennessy was himself convinced that the system in use was only "an incentive to the formation of a thoughtless, idle, and indolent character." And at Cape Coast matters were still more unpromising. In 1872 the government chaplain calls loudly for compulsory education, because he cannot induce the scholars to attend to their duties.

That the fault does not lie with the natives is very satisfactorily shown by Mr. Hennessy. On his second visit to Lagos, King Docemo told him that all his chiefs and principal people were most desirous of having their children educated, but they did not want their religious ideas to be interfered with. The king's own son was obliged to quit a school under English control, being unwilling to believe in the teachers' "mission to enlighten the natives in matters of religion." *All* the "chiefs and captains of companies" at Cape Coast assured Governor Hennessy that "they would give any thing for a good education;" but their religion must not be interfered with. A few low-caste natives, they said, in hopes of promotion to clerkships and catechistships, would continue to frequent the English schools; but the only result would be "flagrant hypocrisy and idleness."

The same testimony was given by all the native chiefs whom Mr. Hennessy met. Bey Inca, King of the Small Scarcies, had sent his son to the Portuguese settlements, to learn Arabic and Portuguese, and he was about sending him now to Senegal, to learn French, and to complete his Arabic. That youth would one day be the ruler of a country on the border of the British settlement of Sierra Leone, and yet he would be ignorant of the English language—a thing deeply to be regretted, thought King Inca.

Purification of Bone-Black.—The refined bone-black of commerce is seldom possessed of the qualities usually ascribed to it. Its decolorizing properties are weak, and, besides, it always contains sulphate of lime, which dissolves in the liquids to be clarified. Herr Gräger, in *Dingler's Journal*, gives the following process for purifying bone-black: It is to be ground to powder, and then boiled in from four to six times its weight of water, containing 4 or 5 per cent. of carbonate of soda. After standing four days, the water is drawn off, and hot water poured on instead. This having been in turn drawn off, the bone-black is next treated with commercial chlorhydric acid, and again heated. The latter treatment is followed until the liquid is no longer turbid from the presence of ammonia. The amount of acid to be used is much greater than is commonly supposed. The next step is to wash with common water, to filter with distilled water, and to dry the bone-black at a temperature of from 212° to 248° Fahr. One hundred parts of crude bone-black yield 20 parts refined. The product is a light powder, very fine, with intense decolorizing power, and but a small quantity need be used to produce the required effect.

The Mistletoe.—The following, over the signature of R. W. Newberry, occurs in the *New York World:* "About last Christmas-time I noticed on two occasions in the *World* that the existence of the 'mistletoe' in this country was doubted. I knew of its existence, but didn't want to make the assertion till I had the proof, which I enclose herewith. I found it on Staten Island many years ago growing on pepperidge-trees. In Maryland it affects the same tree, and also the oak. There is plenty in Virginia, and the specimen I send you was collected from a persimmon-tree at the Bangle Gold-Mine, near Concord, Cabarrus County, N. C., which place I had occasion to visit last week. The number of days it has been gathered and the journey have rather spoiled the sample."

Prof. S. Lockwood says that the false, or American Mistletoe, used to be found on the *Nyssa multiflora*, the pepperidge, or gum-tree, in Mercer County, N. J., which probably is its northern limit in the Eastern States. But this is not the true mistletoe of Europe, which belongs to the genus *Viscum.* The American parasite is the *Phoradendron flavescens.* It infests a number of the deciduous trees, and almost covers some of the oak-trees in Plaquemine Parish, La. The professor says that he received specimens in full bloom, last January, from that locality.

The statements of the Torrey Botanical Club, in regard to certain illusions concerning the English mistletoe, will be interesting in this connection. The idea that the English plant is limited to the oak is an error, it being believed that it is not to be found on more than three oak-trees in all Great Britain. There are but few people in England that have seen it grow at all, and they have generally found it on the apple and wild-crab trees. And yet, as a decoration, with holly, ivy, and laurel, it abounds at Christmas, and is bought with these plants at twopence a bunch. This genuine English mis-

[illegible]

[illegible] Long [illegible] attention was called to the tenacity of [illegible] life when exposed to poisons. I [illegible] forced by the claims of justice to take [illegible] a toxicological examination of the internal organs of a person who had been [illegible] months buried. These were put in a [illegible] glass jar and the jar filled with water. It was summer. A small portion of the [illegible] rose above the fluid. In three or four days I noticed the presence of a great number of large white larvæ, doubtless of the common blow-fly. We obtained enough [illegible] chloride of mercury to establish the fact

[illegible] movements [illegible] about. [illegible] some [illegible] and struggle [illegible] exhausted and lie at the bottom [illegible]

M. Plateau, after keeping [illegible] thus under water for a certain length of time, took them out and dried them on blotting-paper. He found that the terrestrial *Coleoptera* recovered after immersion in several instances. [illegible] aquatic swimming *Coleoptera* and [illegible] *era* had no such power of resistance to asphyxia. The author accounts for this by the rapid waste of oxygen caused by the greater activity of the aquatic insects. He also tried the effects of cold and heat on aquatic insects. It was found that these insects, in the latitude of Belgium, can live

[illegible]

[illegible]

[illegible]

[illegible]

NOTES.

[illegible]

[illegible]

[illegible]

[illegible]

water at low tide, near the Narrows entrance to New York harbor, had the odor of the newly-grown wood, and a piece not more than twice the size of one's finger perceptibly scented a drawer for more than a year. "It is certain," says Mr. Lewis, "that the coast, where the trees of which these are the stumps grew, has since undergone a depression of 18 or 20 feet, an event which may have occupied as many centuries."

The eminent chemist, Berthelet, was lately elected a member of the French Academy of Sciences. The honor has come tardily enough, and was conferred only by the very small majority of three, sixty members voting. The *Revue Scientifique* openly charges the academicians who voted against Berthelet with bigotry, their objections being taken against the freethinker rather than against the man of science.

The idea of making each of the several parts of many different machines interchangeable, says the *Bulletin of Wool Manufacture*, is unquestionably of American origin. Its author, a mechanic named Thomas Warner, employed in the Springfield Armory, offered the suggestion to the Ordnance Bureau, Washington, but the idea was scouted as impracticable. Mr. Warner persevered, however, and obtained a trial for his system in the Springfield establishment. It is now followed in all armories throughout this country, as well as in manufactories of sewing-machines, watches, etc. Our contemporary says: "It is this system which enables us to supply all Europe with arms, and to export sewing-machines to all the European nations, notwithstanding the vastly higher cost of our labor."

The statistics of disease and mortality in the manufacturing establishments of the Russian Empire are absolutely startling. The number of such establishments in Russia is estimated at 90,000, and the number of work-people employed in them at 1,000,000. They are subject to numerous diseases of a serious character, among which the *factory-typhus* holds the first place. The sick-rate is from 60 to 70 per cent., and the mean duration of life is only 20 years. Rickets prevail to a deplorable extent among the youth of the working-class, and the effects of a factory-life upon children are described as disastrous. A government commission is to investigate the matter.

De Fonvielle calls the attention of the French Academy of Science to a remarkable passage in a work on Comets, by Hevelius, written in the year 1652; it is in harmony with the most recent observations, and is as follows: "Comets are made up of various nuclei and bodies, and hence these phenomena *do not by any means consist* of *one* solid spherical body or nucleus, as do the planets, but are made up of many different opaque nuclei and bodies, connected together, some rarer and more tenuous matter existing between, and allowing a free passage for the sun's rays."

It is rather amusing to find Mr. Huxley mixed up with a matter of ecclesiastical concernment, but his position as rector of a university in so religious a country as Scotland makes it inevitable. A student of divinity was presented to a "bursary" in the university by the regular patron of the fund, but he was rejected by the Professorial "Senate" on the ground that he was not a member of the Established Kirk. Huxley made a speech in favor of the young man, as did also one of the professors, but the majority was opposed. The lord-rector says that he wants to know "whether the divinity classes of the Scotch universities are the exclusive property of one of the ecclesiastical bodies into which Scotland is divided, and whether the professors are to obey their church or their university?"

A new geological museum is to be founded in the University of Cambridge, as a memorial to the late Prof. Sedgwick. It will be known as the Sedgwick Museum, and is to be made in all respects an institution worthy of that eminent man. At the meeting held for the purpose of devising means for erecting this memorial, Prof. Humphry remarked "that for more than 54 years Sedgwick had expended £300 a year on the old museum." The committee charged with the work of obtaining subscriptions for the memorial are much encouraged by the receipt of numerous letters from admirers and old pupils of the deceased, who give every assurance of support.

The population of the United States (excluding Indians not taxed, and the inhabitants of the Territories) was, in 1870, 38,115,641, a gain in ten years of 6,931,897, or 22.22 per cent. The highest gain of population was shown by Kansas, 239.90 per cent.; and Minnesota came next, 155.61 per cent. Louisiana shows a gain of 2.67, and South Carolina of 0.22 per cent. The greatest loss is exhibited by New Hampshire, 2.38 per cent.; and Maine comes next, with a loss of 0.22 per cent. The total increase of the white population was 24.39, and of the colored, 9.21 per cent.

Speaking of the Jewish element in the population of Germany, Virchow says that "it has exerted a mighty influence on our progess in civilization."

THE

POPULAR SCIENCE MONTHLY.

AUGUST, 1873.

ELECTRIC TELEGRAPHS.[1]

By Prof. A. P. DESCHANEL.

THE discovery that electricity could be transmitted instantaneously to great distances at once suggested the idea of employing it for signalling. Bishop Watson performed several experiments of this kind in the neighborhood of London, the most remarkable being the transmission of the discharge of a Leyden jar through 10,600 feet of wire suspended between wooden poles at Shooter's Hill. This was in 1747. A plan for an alphabetical telegraph to be worked by electricity is minutely described in the *Scot's Magazine* for 1753, but appears to have been never experimentally realized. Lesage, in 1774, erected at Geneva a telegraph-line, consisting of twenty-four wires connected with the same number of pith-ball electroscopes, each representing a letter. Reusser, in Germany, proposed, in the same year, to replace the electroscopes by spangled panes exhibiting the letters themselves. The difficulty of managing frictional electricity was, however, sufficient to prevent these and other schemes founded on its employment from yielding any useful results. Volta's discoveries, by supplying electricity of a kind more easily retained on the conducting wires, afforded much greater facilities for transmitting signals to a distance.

Several suggestions were made for receiving-apparatus to exhibit the effects of the currents transmitted from a voltaic battery. Sömmering, of Munich, in 1811, proposed a telegraph, in which the signals were given by the decomposition of water in thirty-five vessels, each connected with a separate telegraph-wire. Ampère, in 1820, proposed to utilize Œrsted's discovery by employing twenty-four needles, to be deflected by currents sent through the same number of wires; and Baron Schilling exhibited, in Russia, in 1832, a telegraphic model, in

[1] Abridged from Deschanel's "Natural Philosophy," Part III.: "Electricity and Magnetism."

which the signals appear to have been given by the deflections of a single needle. Sir Francis Ronalds, before 1823, sent intelligible messages through more than eight miles of wire insulated and suspended in the air. His elementary signal was the divergence of the pith-balls of a Canton's electrometer produced by the communication of a statical charge to the wire. He used synchronous rotation of lettered dials at each end of the line, and charged the wire at the sending end whenever the letter to be indicated passed an opening provided in a cover; the electrometer at the far end then diverged, and thus informed the receiver of the message which letter was designated by the sender. The dials never stopped, and any slight want of synchronism was corrected by moving the cover.

Weber and Gauss carried out Schilling's plan in 1833 by leading two wires from the Observatory of Göttingen to the Physical Cabinet, a distance of about 9,000 feet. The signals consisted in small deflections of a bar-magnet, suspended horizontally with a mirror attached, on the plan since adopted in Thomson's mirror galvanometer.

At their request, the subject was earnestly taken up by Prof. Steinheil, of Munich, whose inventions contributed more perhaps than those of any other single individual to render electric telegraphs commercially practicable. He was the first to ascertain that earth-connections might be made to supersede the use of a return wire. He also invented a convenient telegraphic alphabet, in which, as in most of the codes since employed, the different letters of the alphabet are represented by different combinations of two elementary signals. Two needles were employed, one or the other of which was deflected according as a positive or a negative current was sent, the deflections being always to the same side. Sometimes the needles were merely observed by eye, sometimes they were made to strike two bells, and sometimes to produce dots, by means of capillary tubes charged with ink, on an advancing strip of paper, thus leaving the permanent record on the strip in the shape of two rows of dots. His currents were magneto-electric, like those of Weber and Gauss.

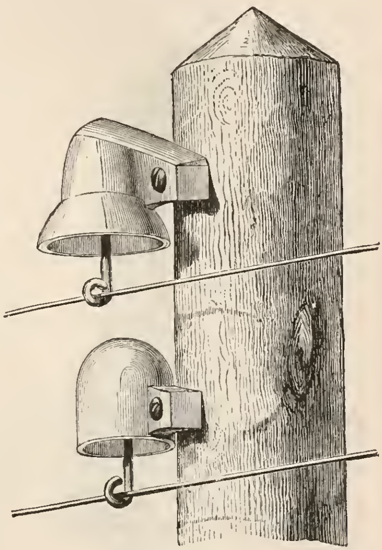
The attraction of an electro-magnet on a movable armature furnishes another means of signalling. This was the foundation of Morse's telegraphic system, and was employed by Wheatstone for ringing a bell to call attention before transmitting a message.

About the year 1837 electric telegraphs were first established as commercial speculations in three different countries. Steinheil's system was carried out at Munich, Morse's in America, and Wheatstone and Cooke's in England. The first telegraphs ever constructed for commercial use were laid down by Wheatstone and Cooke on the London & Birmingham and Great Western Railways. The wires, which were buried in the earth, were five in number, each acting on a separate needle; but the expensiveness of this plan soon led to its being given up. The single-needle and double-needle telegraphs of the same inventors have been much more extensively used, the former requiring only one wire, and the latter two.

All public telegraphs have now for many years been worked by voltaic currents; the magneto-electric system, which was tried on some lines, having been found to involve a needless expenditure of labor.

According to Mr. Culley, engineer-in-chief to the post-office, the battery which had been adopted by the authorities of that department is a modified Daniell's, consisting of a teak trough, divided into cells by plates of glass or slate, and well coated with marine glue, each cell being divided into two by a slab of porous porcelain. The zinc plates measure four inches by two, and the copper plates, which are very thin, are four inches square. The zinc hangs at the upper part of its cell, which is filled with dilute solution of sulphate of zinc. The copper cell is filled with a saturated solution of sulphate of copper, and crystals of this salt are placed at the bottom. The expenditure in sulphate of copper is about a pound and a half for each cell per annum.

Fig. 1.



Insulators.

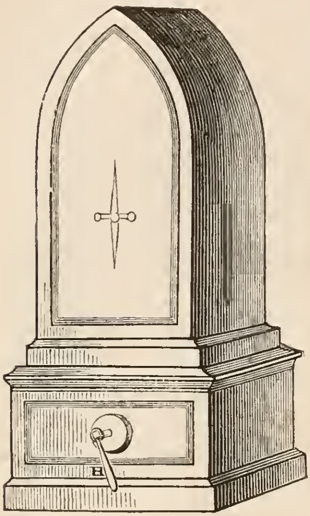
The wires for land-telegraphs are commonly of what is called galvanized iron, that is, iron coated with zinc, supported on posts by means of glass or porcelain insulators, so contrived that some part of the porcelain surface is sheltered from rain, and insulates the wires from the posts, even in wet weather. Wires thus suspended are called *air-lines.*

Underground wires are, however, sometimes employed. They are insulated by a coating of gutta-percha, and are usually laid in pipes, an arrangement which admits of their being repaired or renewed without opening the ground except at the drawing-in boxes. There is less leakage of electricity from subterranean than from air lines, but their cost is greater, and they are less suited for rapid signalling on account of the retardation caused by the inductive action between the wire and the conducting earth, which is similar to that between the two coatings of a Leyden jar.

The early inventors of electric telegraphs supposed that a current could not be sent from one station to another without a return-wire to complete the circuit. Steinheil, while conducting experiments on a railway, with the view of ascertaining whether the rails could be employed as lines of telegraph, made the discovery that the earth would serve instead of a return-wire, and with the advantage of diminished resistance; the earth, in fact, behaving like a return-wire of infinitely great cross-section, and therefore of no resistance.

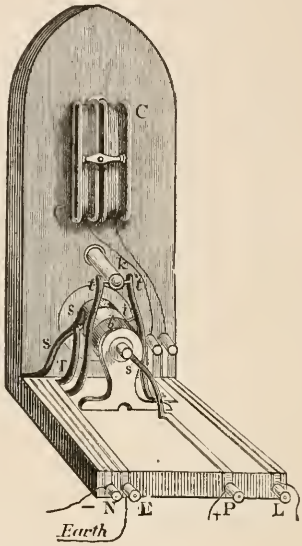
We are not, however, to suppose that the current really returns from the receiving to the transmitting station through the earth. The duty actually performed by the earth consists in draining off the opposite electricities which would otherwise accumulate in the terminals. It keeps the two terminals at the same potential; and, as long as this condition is fulfilled, the current will have the same strength as if the terminals were in actual contact.

Fig. 2.



Single-needle Instrument.

Fig. 3.

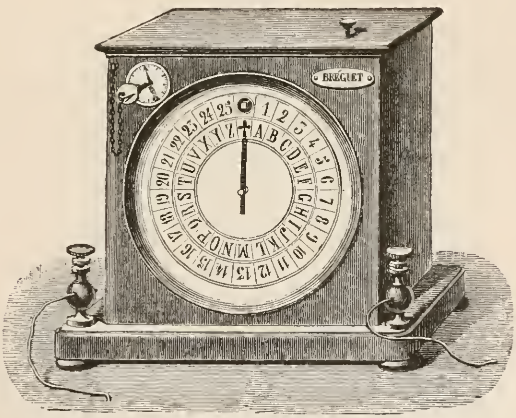


Internal Arrangements.

One of the best-known telegraphs in England, though little or not at all employed elsewhere, is the single-needle instrument of Wheatstone and Cooke, represented in Figs. 2 and 3, the former showing its external appearance, and the latter its internal arrangements as seen from behind. The needle, which is visible in front, is one of an astatic pair, its fellow being in the centre of the coil (C C). When the handle (H) hangs straight down, the instrument is in the position for receiving signals from another station. The current from the line-wire enters at L, and, after traversing the coil and deflecting the needle, escapes through the earth-wire (E), having taken in its course the two tall contact-springs (*t t′*).

To send a current to another station, the handle (H) is moved to one side, and the current sent will be positive or negative according to the side to which the handle is moved. The handle turns the cylindrical arbor (a b), which is divided electrically into two parts by an insulator in the middle of its length. Each of these parts has a pin projecting from it, one pin being above, and the other below. These are vertical when the handle is vertical, and are then doing no duty; but, when the handle is put to one side, the upper pin (which is attached to b) makes contact with one of the tall springs (t t'), at the same time pushing it away from the metallic rest (k), and thus putting it out of connection with the other tall spring; while the lower pin (which is attached to a) makes contact with one of two short springs (T T′), only one of which is shown in the figure. There is permanent connection between a and the negative pole of the battery through the spring s, and between b and the positive pole through the spring s'. In the position represented in the figure, a serves to connect the negative pole of the battery with the earth, and b serves to connect the positive pole with the spring t', down which the current passes from the point of contact of the pin, and then through the coil to the line-wire at L. The needle of the sending station is thus deflected to the same side as that of the receiving station.

Fig. 4.



Breguet's Indicator.

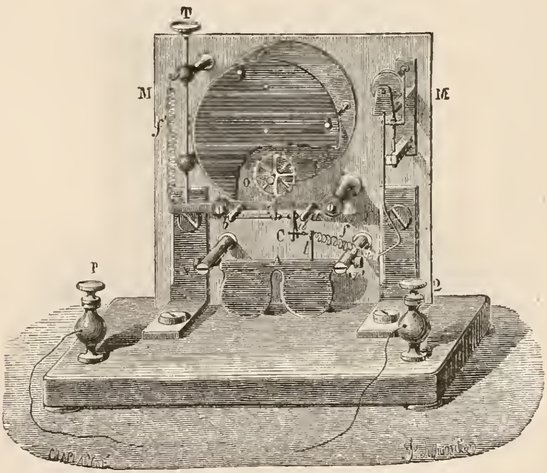
If the handle were moved to the other side, b would serve to connect the positive pole with the earth, and a would establish connection between the negative pole and the coil, which is itself connected with the line-wire.

Since the English telegraphs came into the hands of the post-office, the alphabet devised by Wheatstone and Cooke has been given up, and the Morse alphabet, which we give in a later section, adopted in its place. In the Morse alphabet, which is now the telegraphic alphabet of all nations, the shortest signs are allotted to those letters which occur most frequently. This was not the case with the old needle-alphabet, which was rather planned with the view of assisting the memory; and experience has shown that such assistance is quite unnecessary. The needle instrument is also, to a great extent, being superseded by Morse's instrument.

Telegraphs in which the ordinary letters of the alphabet are ranged round the circumference of a dial, and are pointed at by a revolving hand, are specially convenient for those who are not professional telegraphists. They are constructed on the principle of step-by-step motion, the hand being advanced by successive steps, each representing one current sent or stopped.

One of the simplest instruments of this class is Breguet's, which is extensively used on the French railways. Fig. 4 represents the exterior of the receiving instrument. The dial is inscribed with the 25 letters of the French alphabet and a cross, making 26 signals in all. The hand (as in other step-by-step telegraphs) advances only in one direction, which is the same as that of the hands of a clock, stopping before each letter which is to be indicated, and pointing to the cross at the end of each word. Fig. 5 shows the mechanism by which the

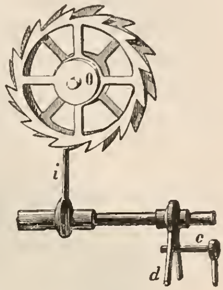
FIG. 5.



MECHANISM OF INDICATOR.

motion is produced. A is the armature of an electro-magnet, the magnet itself being removed in the figure to allow the other parts to be better seen. The two dotted circles traced on the armature represent vertical sections of the two coils, which rest on the bottom of the box, and have their axes horizontal. If introduced, they would nearly conceal the armature from view. The armature turns about an horizontal axis (V V′), and is attached to an opposing spring which draws it back from the magnet. The tension of this spring can be regulated by means of a lever acted on by a key outside the box. When a current is sent, the armature is attracted to the magnet; when the current ceases, the spring draws it back; and it thus moves continually to and fro during the transmission of a message. An upright arm (*l*) is attached to the armature, and carries an horizontal arm (*c*), which lies between the two prongs of a fork (*d*), represented on a larger scale in Fig. 6. This fork vibrates about an horizontal axis (*a b*), to which is attached the vertical pallet (*i*). This pallet acts upon an escapement-wheel (O), toothed in a peculiar way, the thickness of the teeth being only half the thickness of the wheel, and the teeth on one-half of the thickness being opposite the spaces on the other half. The total number of teeth is 26, thirteen on each half of the thickness.

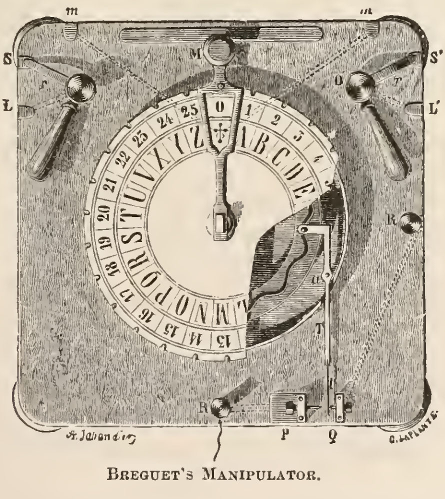
Fig. 6.



Escapement.

When no current is passing, the pallet (*i*) is engaged with one of the teeth on the remote side, as represented in Fig. 6. When a current passes, the armature is attracted, and the pallet is moved over to

Fig. 7.

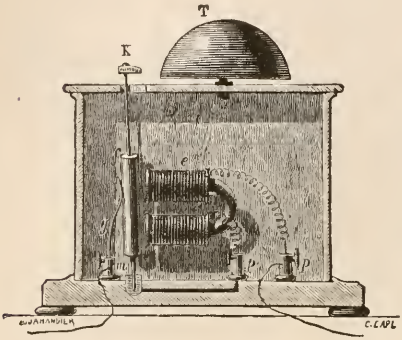


Breguet's Manipulator.

the near side, thus releasing the tooth with which it was previously engaged, and becoming engaged with the next tooth on the near side of the wheel. The wheel, which is urged by a clock-movement, thus advances $\frac{1}{26}$ of a revolution; and the hand on the dial, being attached to the wheel, moves forward one letter. When the current ceases, the pallet moves back to the remote side, and the hand is advanced another letter. If the hand is initially at the cross, it will be advanced to any required letter by so arranging matters that the number of currents *plus* the number of interruptions shall be equal to the number denoting the place of the letter in the alphabet. To effect this arrangement is the office of the sending instrument.

This is represented in Fig. 7. There is a dial inscribed with 25 letters and a cross, like that of the receiving instrument, and an arm which can be carried round the dial by a handle (M). There are 26 notches cut in the edge of the dial, in which a pin attached to the movable arm catches; and the arm is allowed sufficient play to and from the face of the dial to admit of this pin being easily released or inserted. When the pin is in one of the notches, the instrument is in position for transmitting the corresponding letter. The action is as follows: A toothed or rather undulated wheel is fixed on the same axis as the revolving arm, and turns with it. There are 13 projections and 13 hollows on its circumference, a few of which are shown in the figure where the face is cut away. A bent lever (T), movable about an axis at a, bears at one end against the circumference of the undulated wheel, while its other end plays between two points (P, Q), and is in contact with one or other of these points whenever its upper end bears against a hollow or a projection. P is in connection with a battery, and Q with the earth, the undulated wheel being in connection with the line-wire. The movement of the handle thus produces the requisite number of currents and interruptions.

Fig. 8.



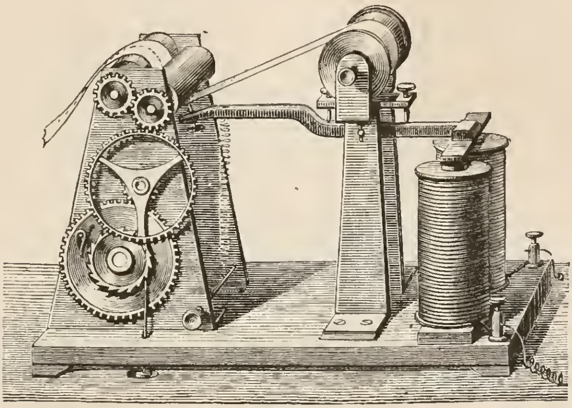
Vibrating Alarum.

Besides the sending and receiving apparatus above described, each station has an *alarum*, which is employed to call attention before sending a dispatch. There are several different kinds. Fig. 8 represents the *vibrating alarum*, which is one of the simplest. It contains an electro-magnet (e), with an armature (f), fixed to the end of an elastic plate. When no current is passing through the coil, the armature is held back by the elasticity of this plate, so as to press against a contact-spring (g) connected with the binding-screw (m). The terminals of the coil are at the binding-screws (p, p'), the former of which is in connection with the armature, and the latter with the earth. As long as the armature presses against the spring (g), there is communication between the two binding-screws (m and p') through the coil; but the passing of a current produces attraction of the armature, which draws it away from g, and interrupts the current. The electro-magnet is thus demagnetized, and the armature springs back against g, so as to allow a fresh current to pass. The armature is thus kept in continual vibration; and a hammer (K), which it carries above, produces repeated strokes on a bell (T).

Morse's apparatus, first tried in America about 1837, is now perhaps the most extensively used of all.

His receiving instrument, or *indicator*, in its primitive simplicity, consists (Fig. 9) of an electro-magnet, a lever movable about an axis, carrying a soft-iron armature at one end, and a pencil at the other, and a strip of paper which is drawn past the pencil by a pair of rollers.

Fig. 9.

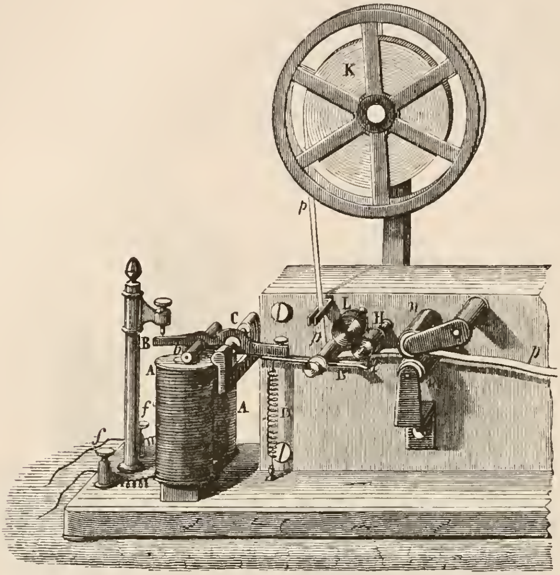


Morse's Telegraph.

As the pencil soon became blunt, and was uncertain in its marking, a point, which scratched the paper, was substituted. This has now, to a great extent, been superseded by an ink-writer, which requires the exertion of less force, and at the same time leaves a more visible trace.

Fig. 10 represents Morse's indicator as modified by Digney. A train of clock-work, not shown in the figure, drives one pair of rollers ($n\ m$), which draw forward a strip of paper ($p\ p$) forming part of a long roll (K). The same train turns the printing-cylinder (H), the surface of which is kept constantly charged with a thick, greasy ink by rolling-contact with the ink-pad (L). The armature (B B′) of the electro-magnet (A) is mounted on an axis at C, and carries a style at its extremity just beneath the printing-cylinder. When a current passes, the armature is attracted, and the style presses the paper against the printing-cylinder, causing a line to be printed on it, the length of which depends on the duration of the current, as the paper continues to advance without interruption. The lines actually employed are of two lengths, one being made as short as possible (-), and called a *dot*, and the other being about three times as long (—), and called a *dash*. The opposing spring (D) restores the armature to its original position the moment the current ceases.

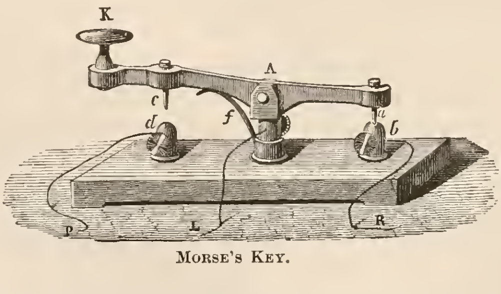
Fig. 10.



Morse's Telegraph—Modified Form.

Morse's key (Fig. 11) is simply a brass lever, mounted on a hinge at A, and pressed up by the spring *f*. When the operator puts down the key, by pressing on the button (K) with his finger, the projections

Fig. 11.



Morse's Key.

(*c d*) are brought into contact, and a current passes from the battery-wire (P) to the line-wire (L). When the key is up, the projections (*a b*) are in contact, and currents arriving by the line-wire pass by the wire R to the indicator or the relay. By keeping the key down for a longer or shorter time, a dash or a dot is produced at the station to which the signal is sent. The dash and dot are combined in different ways to indicate the different letters, as shown in the following scheme, which is now generally adopted both in Europe and America :

MORSE'S ALPHABET.

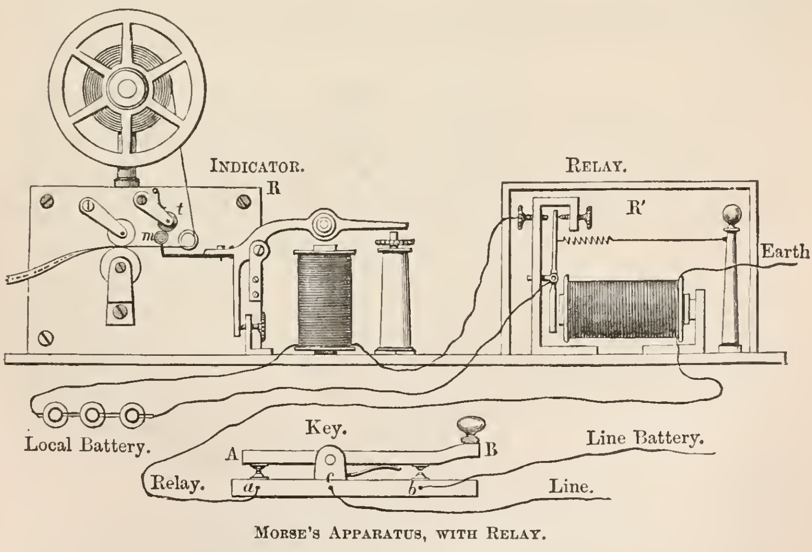
A - —	J - — — —	T —	1 - — — — —
Ä - — - —	K — - —	U - - —	2 - - — — - -
B — - - -	L - — - -	Ü - - — —	3 - - - — —
C — - — -	M — —	V - - - —	4 - - - - —
D — - -	N — -	W - — —	5 - - - - -
E -	O — — —	X — - - —	6 — - - - -
É - - — - -	Ö — — — -	Y — - — —	7 — — - - -
F - - — -	P - — — -	Z — — - -	8 — — — - -
G — — -	Q — — - —	Ch — — — —	9 — — — — -
H - - - -	R - — -		0 — — — — —
I - -	S - - -	Understood - - - — -	

A space about equal to the length of a dash is left between two letters, and a space of about twice this length between two words.

In needle-telegraphs, the dot is represented by a deflection to the left, and the dash by a deflection to the right.

Fig. 12 represents Morse's indicator in connection with what is

FIG. 12.



MORSE'S APPARATUS, WITH RELAY.

called a *relay ;* that is to say, an apparatus which, on receiving a feeble current from a distance, sends on a much stronger current from a battery on the spot. The key (B) being up, a current arriving by the line-wire passes through the key from *c* to *a*, thence through another wire to the coil of the electro-magnet belonging to the relay, and through this coil to earth. The electro-magnet of the relay attracts an armature, the contact of which with the magnet completes the circuit of the local battery, in which circuit the coil belonging to the indicator is included. The armature of the indicator is thus compelled to follow the movements of the armature of the relay.

Relays are used when the currents which arrive are too much enfeebled to give clear indications by direct action. They are also frequently introduced at intermediate points in long lines which could not otherwise be worked through from end to end. The analogy of this use to change of horses on a long journey is the origin of the name. Relays are also frequently used in connection with alarums when these are large and powerful.

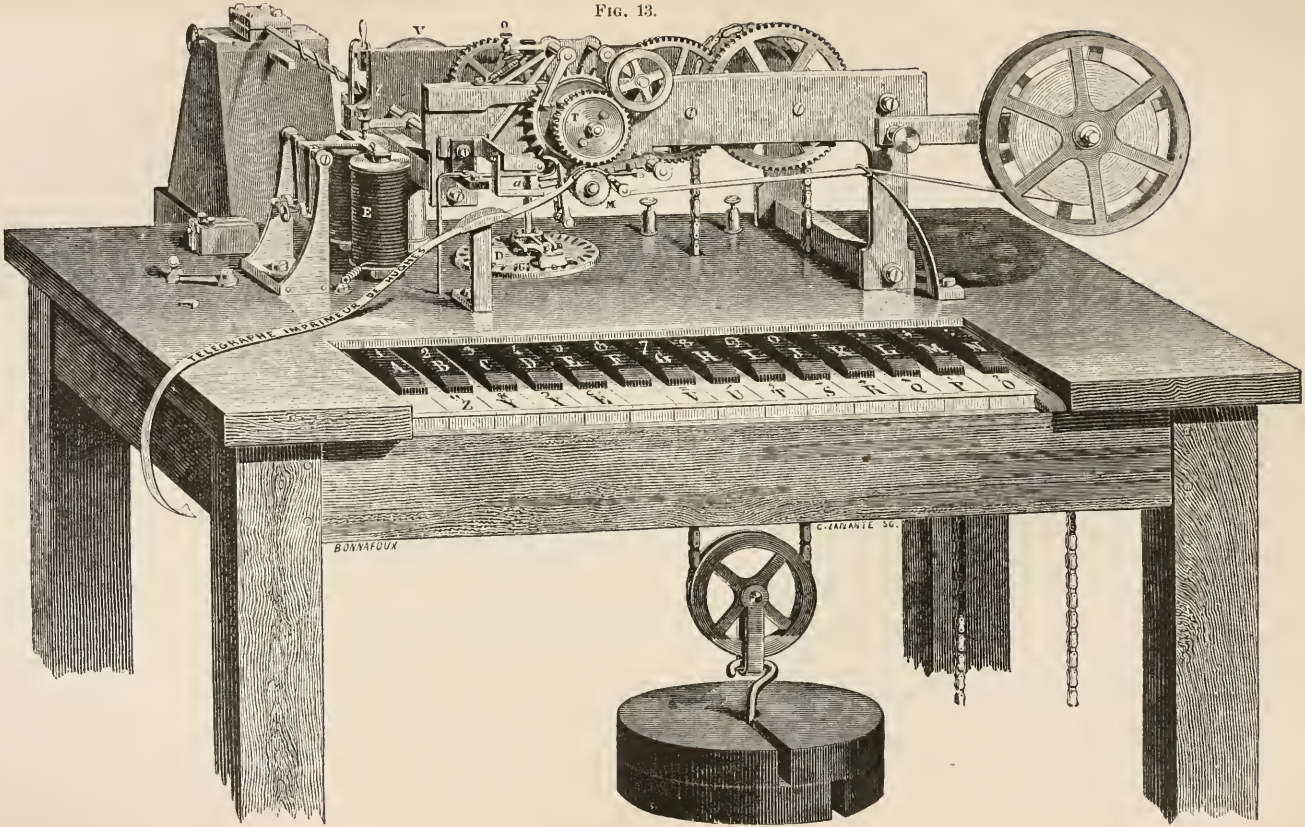
The employment of Morse's alphabet requires on the average about three currents to be sent per letter. The extension of telegraphic service has stimulated the industry of inventors to devise means for obtaining more rapid transmission. Hughes, about 1859, invented a system which requires only one current to be sent for each letter, and which, accordingly, sends messages in about a third of the time required by Morse's method. Hughes's machine also prints its messages in Roman characters on a strip of paper. These advantages are, however, obtained at the expense of extreme complexity in the apparatus employed. It is only fit for the use of skilled hands; but it is extensively employed on important lines of telegraph. We will proceed to indicate the fundamental arrangements of this marvellous piece of ingenuity.

Fig. 13 is a general view of the machine. It is propelled by powerful clock-work, with a driving weight of about 120 lbs., and with a regulator consisting of a vibrating spring (*l*) acting upon a 'scape-wheel. A travelling weight on the spring can be moved toward either end to regulate the quickness of the vibrations. The clock-work drives three shafts or axes: 1. The type-shaft, so called because it carries at its extremity the type-wheel (T), which has the letters of the alphabet engraved in relief on its circumference at equal distances, except that a blank space occurs at one place instead of a letter; 2. The printing-shaft, which turns much faster than the type-shaft, making sometimes 700 revolutions per minute, and carrying the fly-wheel (V). These two axes are horizontal, and are separately represented in Fig. 14; 3. A vertical shaft (*a*) having the same velocity as the type-wheel, which drives it by means of bevel-wheels.

This vertical shaft consists of two metallic portions, insulated from each other by an ivory connecting-piece. In the position represented in Fig. 14, these two metallic parts are electrically connected by means of the screw (V), but they will be disconnected by raising the movable piece (*v*).

The revolving arm composed of the pieces *v' v* is called the *chariot.*

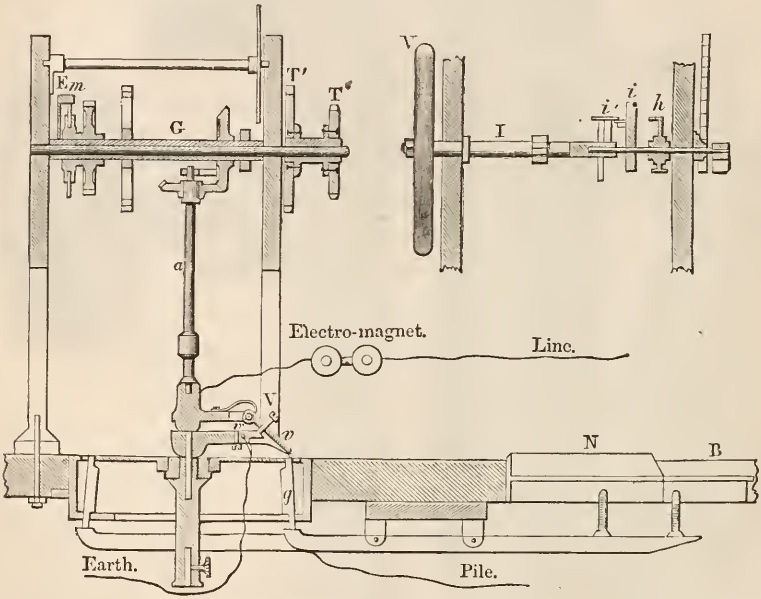
Fig. 13.



Hughes's Printing Telegraph.

It revolves with the vertical shaft, and travels over a disk (D) pierced with as many holes as there are letters on the type-wheel, these holes being ranged in a circle round the base of the shaft, and at such a distance from the shaft that the extremity of the chariot passes exactly over them. In these holes are the upper ends of a set of pins (*g*), which are raised by putting down a set of keys (B N) resembling those of a piano. When the chariot passes over a pin which is thus raised, the piece *v* is lifted away from *v*′, and the current from the battery, which previously passed from the pin through *v* and *v*′ to the earth, is now cut off from *v*′, and passes through *v* to the electro-magnet, and thence to the line-wire.

Fig. 14.



Type-shaft and Printing-shaft.

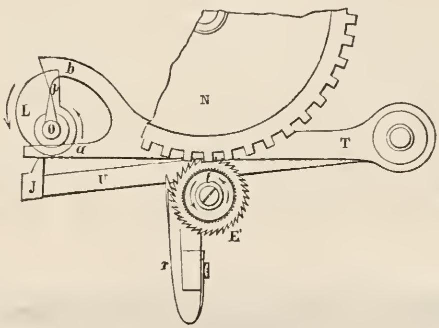
This is the process for sending signals. We will now explain how a current thus sent causes a letter to be printed by the type-wheels at both the sending and receiving stations, the sending and receiving instruments being precisely alike.

The current traverses the coils of an electro-magnet (E, Fig. 13), beneath which is a permanent steel horseshoe magnet, having its poles in contact with the soft-iron cores of the electro-magnet. When no current is passing, the influence of the steel renders these cores temporary magnets, and enables them to hold the movable armature (*p*) against the force of an opposing spring. The current is in such a direction that it tends to reverse the magnetism induced by the steel. It is not necessary, however, that it should be strong enough to produce an actual reversal, but merely that it should weaken the induced magnetism of the cores sufficiently to enable the opposing spring to overpower them. This is one of the most original parts of Hughes's apparatus, and is a main cause of its extreme sensibility.

The printing-shaft consists of two portions, one of which (I, Fig. 14) carries the fly-wheel (V), and turns uniformly under the action of the clock-movement; the other, which is next the front of the machine, remains at rest when no current is passing; but, when the armature of the magnet rises, the two parts of the shaft become locked together by means of the ratchet-wheel and click (*i i'*).

The portion of the shaft which is thus turned every time a current passes, carries a very acute cam or tooth (*p*, Fig. 15), which suddenly raises the lever (*a b*), movable about an axis at one end (T), and, by so doing, raises the paper against the type-wheel, and prints the letter. In order thus to print a letter from the rim of a wheel which continues turning, very rapid movement is necessary. This is secured by making the opposing spring which moves the armature very powerful, and the cam (*p*) very acute. The same movement of the lever which produces

Fig. 15.



Mechanism for Printing.

the impression, raises the arm (J U), which carries a spring (*r*) with a click at its extremity. This click, in its ascent, glides over the teeth of the ratchet-wheel (E), but locks into the teeth and turns the wheel in its descent, and, by so doing, advances the paper through the distance corresponding to one letter. The spacing of the words is obtained by the help of the blank on the type-wheel.

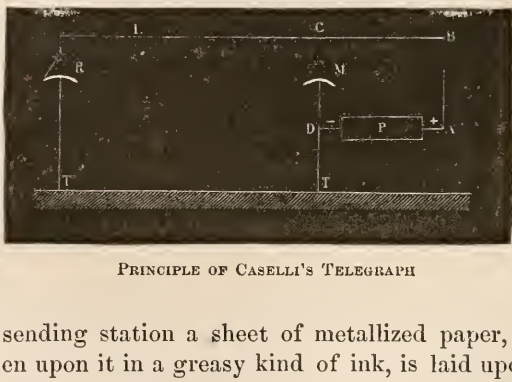
The type-wheel should admit of easy adjustment to restore it to agreement with the chariot when accidental derangement may have occurred. For this purpose the shaft (G) is made hollow, its internal and external portions being merely locked together by the click (*m*), which is held in its place by a permanent current in either direction. On pressing down the button (Q, Fig. 13), the click (*m*) is raised by the piece E, so as to leave the type-wheel free, and a pin is provided which catches in a notch corresponding to the blank on the type-wheel. The adjustment can also be made by hand.

Lastly, the shaft (I) carries a third cam, which, at each revolution of this axis, engages with a very coarse-toothed wheel (T′), set on the same axis as the type-wheel, and pushes it a little forward or backward without detaching it from the driving-gear. Small discrepancies between the velocities of the type-wheel and chariot are thus corrected as often as a letter is printed. This contrivance serves to keep the receiving instrument from gaining or losing on the sending instrument during the transmission of a message. The type-wheel of the receiving instrument must be adjusted before the message begins, so as to make the two instruments start at the same letter.

Suppose a metallic cylinder, permanently connected with the earth, to be revolving, carrying with it on its surface a strip of paper freshly impregnated with cyanide of potassium. Also suppose a very light steel point permanently connected with the line-wire, and resting in contact with the paper. Every time that a current arrives by the line-wire, chemical action will take place at the point of contact, and the paper at this point will be discolored by the formation of Prussian blue. This is the principle of Bain's electro-chemical telegraph, which leaves a record in the shape of dots and dashes of Prussian blue. The apparatus for sending signals is the same as in Morse's system. The paper must not be too wet, or the record will be blurred; neither must it be too dry, for then no record will be obtained.

An autographic telegraph is one which produces at the receiving station a fac-simile of the original dispatch. The best known-instruments of this class are those of Bonelli and Caselli. We shall describe the latter.

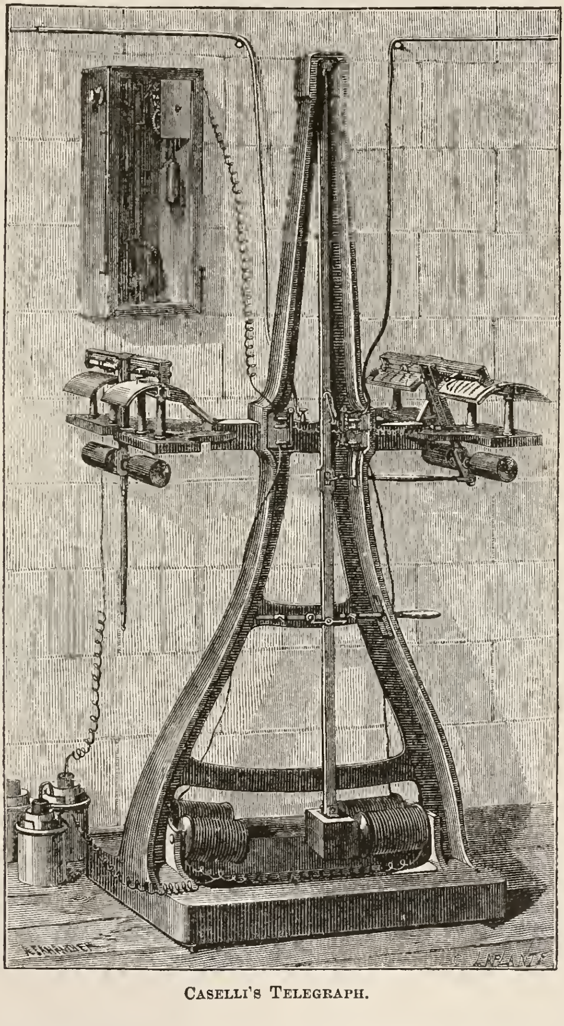
Fig. 16.



Principle of Caselli's Telegraph

At the sending station a sheet of metallized paper, with the dispatch written upon it in a greasy kind of ink, is laid upon a cylindric surface (M, Fig. 16). At the receiving station there is a similar cylindric surface (R), on which a sheet of Bain's chemical paper is laid. Two styles, driven by pendulums which oscillate with exact synchronism, move over the surfaces of the two sheets, describing upon them very close parallel lines at a uniform distance apart, both styles being in permanent connection with the line-wire. The current is furnished by the battery (P) at the sending station. When the style is on a conducting portion of the paper M, the current takes the course of least resistance (ABCD), no sensible portion of it going to the other station. On the other hand, when the style is on the non-conducting

Fig. 17.



Caselli's Telegraph.

ink in which the dispatch is written, the circuit ABCD is broken, and the current travels through the line-wire. At this moment the style on the sheet R is in exactly the same position as that on the sheet M, by reason of the synchronism of the pendulums, and a blue line will be produced which will be the exact reproduction of the broken line of the dispatch traversed by the style. Accordingly, when the style of M has described a series of lines close together and covering the sheet, R will be covered with a series of points or lines forming a copy of the dispatch. The tracing point is carried by a lever turning about an axis near its lower end. To this lower end is attached a connecting rod, jointed at its other end to the pendulum (Fig. 17). While the pendulum swings in one direction, the style traces a line in one direction on the sheet. At the end of this stroke, an action occurs which, besides advancing the style, raises it, so that it does not touch the sheet during the return-stroke.

The synchronism of the pendulums at the two stations, which is absolutely necessary for correct working, is obtained by means of two clocks which are separately regulated to a given rate, the clock-pendulums making two vibrations for one of the telegraphic pendulum. The bob of the latter consists of a mass of iron, and vibrates between two electro-magnets, which are made and unmade according to the position of the clock-pendulum, as the latter makes and breaks the circuit of a local battery. The mass of iron is thus alternately attracted by each of the two magnets as it comes near them, and is prevented from gaining or losing on the clock.

Fig. 18.

Fac-simile of Dispatch.

Fig. 19.

Copy on Tin-foil.

It is evident that the Caselli telegraph may be applied to copy not only letters, but a design of any kind; hence the name of *pantelegraph* which has been given it. Fig. 18 represents a copy thus obtained upon Bain's paper. Fig. 19 represents a copy obtained at the same time upon a sheet of tin-foil, such as is usually placed beneath the paper. The current decomposes the moisture of the paper, and the hydrogen thus liberated reduces the oxide of tin, of which a small quantity is always present on the surface. If the foil be then treated with a mixture of nitric and pyrogallic acid, the traces are developed, and come out black.

The Caselli system has been used for some years on the telegraphs around Havre and Lyons, but has not realized the hopes of its promoters, its dispatches being often illegible.

Instead of a series of parallel lines, the styles may be made to trace the successive convolutions of a fine helix, the two sheets being bent round two cylinders, which revolve in equal times, and also advance longitudinally.

THE STUDY OF SOCIOLOGY.

By HERBERT SPENCER.

XIII.—*Discipline.*

IN the foregoing eight chapters we have contemplated, under their several heads, those "Difficulties of the Social Science" which the chapter bearing that title indicated in a general way. After thus warning the student against the errors he is liable to fall into, partly because of the nature of the phenomena themselves and the conditions they are presented under, and partly because of his own nature as observer of them—which by both its original and its acquired characters causes twists of perception and judgment—it now remains to say something about the needful preliminary studies. I do not refer to studies furnishing the requisite data, but I refer to studies giving the requisite discipline. Right thinking in any matter depends very much on the *habit* of thought; and the habit of thought, partly natural, depends in part on the artificial influences to which the mind has been subjected.

As certainly as each person has peculiarities of bodily action that distinguish him from his fellows, so certainly has he peculiarities of mental action that give a character to his conceptions. There are tricks of thought as well as tricks of muscular movement. There are acquired mental aptitudes for seeing things under particular aspects, as there are acquired bodily aptitudes for going through evolutions after particular ways. And there are intellectual perversities produced by certain modes of treating the mind, as there are incurable awkwardnesses due to certain physical activities daily repeated.

A truth ever to be remembered is, that each kind of mental discipline, besides its direct effects on the faculties brought into play, has its indirect effects on the faculties left out of play; and when special benefit is gained by extreme special discipline, there is inevitably more or less general mischief entailed on the rest of the mind by the consequent want of discipline. That antagonism between body and brain which we see in those who, pushing brain-activity to an extreme, enfeeble their bodies, and those who, pushing bodily activity to an extreme, make their brains inert, is an antagonism which holds between the parts of the body itself and the parts of the brain itself. The greater bulk and strength of the right arm resulting from its greater use, and the greater aptitude of the right hand, are instances in point; and that the relative incapacity of the left hand, involved by cultivating the capacity of the right hand, would become still more marked were the right hand to undertake all manipulation, is obvious. The like holds among the mental faculties. The fundamental antagonism between feeling and cognition, running down through all actions of the mind, from the conflicts between emotion and reason to the conflicts between sensation and perception, is the largest illustration. We meet with a kindred antagonism, among the actions of the intellect itself, between perceiving and reasoning. Men who have marked aptitudes for accumulating observations are rarely men given to generalizing; while men given to generalizing are commonly men who, mostly using the observations of others, observe for themselves less from love of particular facts than from desire to put such facts to use. We may even trace the antagonism within a narrower range, between general reasoning and special reasoning. One prone to far-reaching speculations rarely pursues to much purpose those investigations by which particular truths are reached; while the scientific specialist ordinarily has but little tendency to occupy himself with wide views.

No more is needed to make it clear that habits of thought result from particular kinds of mental activity, and that each man's habits of thought influence his judgment on any question brought before him. It will be obvious, too, that, in proportion as the question is involved and many-sided, the habit of thought must be a more important factor in determining the conclusion arrived at. Where the subject-matter is very simple, as a geometrical truth or a mechanical action, and has therefore not many different aspects, perversions of view consequent on intellectual attitude are comparatively few; but, where the subject-matter is complex and heterogeneous, and admits of being mentally seen in countless different ways, the intellectual attitude affects very greatly the form of the conception.

A fit habit of thought, then, is all-important in the study of Sociology; and a fit habit of thought can be acquired only by study of the Sciences at large. For Sociology is a science in which the phenomena of all other sciences are included. It presents those necessities of relation with which the Abstract Sciences deal; it presents those connections of cause and effect which the Abstract-Concrete Sciences familiarize the student with; and it presents that concurrence of many causes and production of contingent results which the Concrete Sciences show us, but which we are shown especially by the organic sciences. Hence, to acquire the habit of thought conducive to right thinking in Sociology, the mind must be familiarized with the fundamental ideas which each class of sciences brings into view, and must not be possessed by those of any one class, or any two classes, of sciences.

That this may be better seen, let me briefly indicate the indispensable discipline which each class of sciences gives to the intellect, and also the wrong intellectual habits produced if that class of sciences is studied exclusively.

Entire absence of training in the Abstract Sciences leaves the mind without due sense of *necessity of relation.* Watch the mental movements of the wholly ignorant, before whom not even the exact and certain results of Arithmetic have been frequently brought, and it will be seen that there exists nothing like irresistible conviction that from given data there is an inevitable inference. That which to you has the aspect of a necessity, seems to them not free from doubt. Even men whose educations have made numerical processes and results tolerably familiar, will show, in a case where the implication is logical only, that they have not absolute confidence in the dependence of conclusion on premisses.

Unshakable beliefs in necessities of relation, are to be gained only by studying the Abstract Sciences, Logic and Mathematics. Dealing with necessities of relation of the simplest class, Logic is of some service to this end; though often of less service than it might be, for the reason that the symbols it uses are not translated into thought, and the connections stated not really represented. Only when, for a logical implication expressed in the abstract, there is substituted an example so far concrete that the interdependencies can be contemplated, is there an exercise of the mental power by which logical necessity is grasped. Of the discipline given by Mathematics, also, it is to be remarked that the habit of dealing with the necessities of numerical relation, though in a degree useful for cultivating the consciousness of necessity, is not in a high degree useful; because, in the immense majority of cases, the mind, occupied with the symbols used, and not passing beyond them to the groups of units they stand for, does not really figure to itself the relations expressed—does not really discern their necessities, and has not therefore the conception of necessity perpetually repeated. It is the more special division of Mathematics, dealing with Space-relations, which, above all other studies, yields necessary ideas, and so makes strong and definite the consciousness of necessity in general. A geometrical demonstration time after time presents premisses and conclusion in such wise that the relation alleged is seen in thought—cannot be passed over by mere symbolization. Each step exhibits some connection of positions or quantities as one that could not be otherwise; and hence the habit of taking such steps makes the consciousness of such connections familiar and vivid.

But, while mathematical discipline, and especially discipline in Geometry, is extremely useful, if not indispensable, as a means of preparing the mind to recognize throughout Nature the absoluteness of uniformities, it is, if exclusively or too habitually pursued, apt to produce perversions of general thought. Inevitably it generates a special bent of mind; and inevitably this special bent affects all the intellectual actions—causes a tendency to look in a mathematical way at questions beyond the range of Mathematics. The mathematician is ever dealing with phenomena of which the elements are relatively few and definite. His most involved problem is immeasurably less involved than are the problems of the Concrete Sciences. But he cannot help bringing with him his mathematical habits of thought; and, in dealing with questions which the Concrete Sciences present, he recognizes some few only of the factors, tacitly ascribes to these a definiteness which they have not, and proceeds after the mathematical manner to draw positive conclusions from these data, as though they were specific and adequate.

Hence the truth, so often illustrated, that mathematicians are bad reasoners on contingent matters. To previous illustrations may be added the recent one yielded by M. Michel Chasles, who proved himself incapable as a judge of evidence in the matter of the Newton-Pascal forgeries. Another was supplied by the late Prof. De Morgan, who, bringing his mental eye to bear with microscopic power on some small part of a question, ignored its main features.

By cultivation of the Abstract-Concrete Sciences, there is produced a further habit of thought, not otherwise produced, which is essential to right thinking in general, and by implication to right thinking in Sociology. Familiarity with the various orders of physical and chemical phenomena gives distinctness and strength to the consciousness of *cause and effect.*

Experiences of things around do, indeed, yield conceptions of special forces and of force in general. The uncultured get from these experiences degrees of faith in causation such that, where they see some striking effect, they usually assume an adequate cause, and, where a cause of given amount is manifest, a proportionate effect is looked for. Especially is this so where the actions are simple mechanical actions. Still, these impressions which daily life furnishes, if unaided by those derived from physical science, leave the ordinary mind with but vague conceptions of causal relations. It needs but to remember the readiness with which people accept the alleged facts of the Spiritualists, many of which imply a direct negation of the mechanical axiom that action and reaction are equal and opposite, to see how much the ordinary thoughts of causation lack quantitativeness—lack the idea of proportion between amount of force expended and amount of change wrought. Very generally, too, the ordinary thoughts of causation are not even qualitatively valid; the most absurd notions as to what cause will produce what effect are frequently disclosed. Take, for instance, the popular belief that a goat kept in a stable will preserve the health of the horses; and note how this belief, accepted on the authority of grooms and coachmen, is repeated by their educated employers—as I lately heard it repeated by an American general, and agreed in by two retired English officials. Clearly, the readiness to admit, on such evidence, that such a cause can produce such an effect, implies a consciousness of causation which, even qualitatively considered, is of the crudest kind. And such a consciousness is, indeed, everywhere betrayed by the superstitions prevalent more or less among all classes.

Hence we must infer that the uncompared and unanalyzed observations men make, in the course of their dealings with things around, do not suffice to give them wholly-rational ideas of the process of things. It requires that physical actions shall be critically examined, the factors and results measured, and different cases contrasted, before there can be reached clear ideas of necessary causal dependence. And thus to investigate physical actions is the business of the Abstract-Concrete Sciences. Every experiment which the physicist or the chemist makes brings afresh before his consciousness the truth, given countless times in his previous experiences, that from certain antecedents of particular kinds there will inevitably follow a particular kind of consequent; and that, from certain amounts of the antecedents, the amount of the consequent will be inevitably so much. The habit of thought generated by these hourly-repeated experiences, always the same, always exact, is one which makes it impossible to think of any effect as arising without a cause, or any cause as expended without an effect; and one which makes it impossible to think of an effect out of proportion to its cause, or a cause out of proportion to its effect.

While, however, study of the Abstract-Concrete Sciences, carried on experimentally, gives clearness and strength to the consciousness of causation, taken alone it is inadequate as a discipline; and, when pursued exclusively, generates a habit of thought which betrays into erroneous conclusions when higher orders of phenomena are dealt with. The process of physical inquiry is essentially analytical; and the daily pursuit of this process generates two tendencies—the tendency to contemplate separately the factors of phenomena, which it is the aim of inquiry to disentangle, and identify, and measure, and the tendency to rest in the results of such inquiry as though they were the final results to be sought. The chemist, by saturating, neutralizing, decomposing, precipitating, and at last separating, is enabled to measure what quantity of this element had been held in combination by a given quantity of that; and, when, by some alternative course of analysis, he has verified the result, his inquiry in so far is concluded: as are kindred inquiries respecting the other affinities of the element, when they are qualitatively and quantitatively determined in like ways. His habit is to get rid of, or neglect as much as possible, the concomitant disturbing factors, and to ascertain the nature and amount of some one and then of some other; and his end is reached when accounts have been given of all the factors individually considered. So is it, too, with the physicist. Say the problem is the propagation of sound through air, and the interpretation of its velocity—say that the velocity as calculated by Newton is found less by one-sixth than observation gives, and that Laplace sets himself to explain the anomaly. He recognizes the evolution of heat by the compression which each sound-wave produces in the air; finds the extra velocity consequent on this; adds this to the velocity previously calculated; finds the result answer to the observed fact; and then, having analyzed the phenomenon into its components and measured them, considers his task concluded. So throughout: the habit is that of identifying, parting, and estimating factors, and stopping after having done this completely.

This habit, carried into the interpretation of things at large, affects it somewhat as the mathematical habit affects it. It tends toward the formation of unduly-simple and unduly-definite conceptions; and it encourages the natural propensity to stop short with proximate results. The daily practice of dealing with single factors of phenomena, and with factors complicated by but few others, and with factors ideally separated from their combinations, inevitably gives to the thoughts about surrounding things an analytic rather than a synthetic character. It promotes the contemplation of simple causes apart from the entangled *plexus* of coöperating causes which all the higher natural phenomena show us, and begets a tendency to suppose that, when the results of such simple causes have been exactly determined, nothing remains to be sought.

Physical science, then, though indispensable as a means of developing the consciousness of causation in its simple definite forms, and thus preparing the mind for dealing with complex causation, is not sufficient of itself to make complex causation truly comprehensible. In illustration of its inadequacy, I might name a distinguished mathematician and physicist whose achievements place him in the first rank, but who, nevertheless, when entering on questions of concrete science, where the data are no longer few and exact, has repeatedly shown defective judgment. Choosing premisses which, to say the least, were gratuitous and in some cases improbable, he has proceeded by exact methods to draw definite conclusions, and has then enunciated those conclusions as though they had a certainty proportionate to the exactness of his methods.

The kind of discipline which affords the needful corrective is the discipline which the Concrete Sciences give. Study of the *forms* of phenomena, as in Logic and Mathematics, is needful, but by no means sufficient. Study of the *factors* of phenomena, as in Mechanics, Physics, Chemistry, is also essential, but not enough by itself, or enough even joined with study of the forms. Study of the *products* themselves, in their totalities, is no less necessary. Exclusive attention to forms and factors will not only fail to give right conceptions of products, but will even tend to make the conceptions of products wrong. The analytical habit of mind has to be supplemented by the synthetical habit of mind. Seen in its proper place, analysis has for its chief function to prepare the way for synthesis; and, to keep a due mental balance, there must be not only a recognition of the truth that synthesis is the end to which analysis is the means, but there must also be a practice of synthesis along with a practice of analysis.

All the Concrete Sciences familiarize the mind with certain cardinal conceptions which the Abstract and Abstract-Concrete Sciences do not yield—the conceptions of *continuity*, *complexity*, and *contingency*. The simplest of the Concrete Sciences, Astronomy and Geology, yield the idea of continuity with great distinctness. I do not mean continuity of existence merely; I mean continuity of causation: the unceasing production of effect—the never-ending work of every force. On the mind of the astronomer there is vividly impressed the idea that any one planet which has been by so much swerved out of its course by another planet, or by a combination of others, will through all future time follow a route different from that it would have followed but for the perturbation; and he recognizes its reaction upon the perturbing planet or planets, as similarly having effects which, while ever being complicated and ever slowly diffused, will never be lost during the immeasurable periods to come. So, too, the geologist sees in each change wrought on the earth's crust, by igneous or aqueous action, a new factor that goes on perpetually modifying all subsequent changes. An upheaved portion of sea-bottom alters the courses of ocean-currents, modifies the climates of adjacent lands, affects their rainfalls and prevailing winds, their denudations and the deposits round their coasts, their floras and faunas; and these effects severally become causes that act unceasingly in ever-multiplying ways. Always there is traceable the persistent working of each force, and the progressive complication of the results through succeeding geologic epochs.

These conceptions, not yielded at all by the Abstract and Abstract-Concrete Sciences, and yielded by the inorganic Concrete Sciences in ways which, though unquestionable, do not arrest attention, are yielded in clear and striking ways by the organic Concrete Sciences—the sciences that deal with living things. Every organism, if we choose to read the lessons it gives us, shows continuity of causation and complexity of causation. The ordinary facts of inheritance illustrate continuity of causation—very conspicuously where varieties so distinct as negro and white are united, and where traces of the negro come out generation after generation; and still better among domestic animals, where traits of remote ancestry show the persistent working of causes which date far back. Organic phenomena make us familiar with complexity of causation, both by showing the coöperation of many antecedents to each consequent, and by showing the multiplicity of results which each influence works out. If we observe how a given weight of a given drug produces on no two persons exactly like sets of effects, and produces even on the same person different effects in different constitutional states, we see at once how involved is the combination of factors by which the changes in an organism are brought about, and how extremely contingent, therefore, is each particular change. And we need but watch what happens after an injury, say of the foot, to perceive how, if permanent, it alters the gait, alters the adjustment and bend of the body, alters the movements of the arms, alters the features into some contracted form accompanying pain or inconvenience. Indeed, through the readjustments, muscular, nervous, and visceral, which it entails, this local damage acts and reacts on function and structure throughout the whole body, producing effects which, as they diffuse, complicate incalculably.

While, in multitudinous ways, the Science of Life thrusts on the attention of the student the cardinal notions of continuity, and complexity, and contingency, of causation, it introduces him to a further conception of moment, which the inorganic Concrete Sciences do not furnish—the conception of what we may call *fructifying* causation. For, as it is a distinction between living and not-living bodies that the first propagate while the second do not, it is also a distinction between them that certain actions which go on in the first are cumulative, instead of being, as in the second, dissipative. Not only do organisms as wholes reproduce, and so from small beginnings are capable, by multiplication, of reaching great results; but components of them, normal and morbid, do the like. Thus a minute portion of a virus, introduced into an organism, does not work an effect proportionate to its amount, as would an inorganic agent on an inorganic mass; but, by appropriating materials from the blood of the organism, and thus immensely increasing, it works effects altogether out of proportion to its amount as originally introduced—effects which may continue with accumulating power throughout the remaining life of the organism. It is so with internally-evolved agencies as well as with externally-invading agencies. A portion of germinal matter, itself microscopic, may convey from a parent some constitutional peculiarity that is infinitesimal in relation even to its minute bulk; and from this there may arise, fifty years afterward, gout or insanity in the resulting man: after this great lapse of time, slowly-increasing actions and products show themselves in large derangements of function and structure. And this is a trait characteristic of organic phenomena. While, from the *destructive* changes going on throughout the tissues of living bodies, there is a continual production of effects which lose themselves by subdivision, as do the effects of inorganic forces, there arise from those *constructive* changes going on in them, by which living bodies are distinguished from not-living bodies, certain classes of effects which increase as they diffuse—go on augmenting in volume as well as in variety.

Thus, as a discipline, study of the Science of Life is essential; partly as familiarizing the mind with the cardinal ideas of continuity, complexity, and contingency, of causation in clearer and more various ways than do the other Concrete Sciences, and partly as familiarizing the mind with the cardinal idea of fructifying causation, which the other Concrete Sciences do not present at all. Not that, pursued exclusively, the Organic Sciences will yield these conceptions in clear forms: there requires a familiarity with the Abstract-Concrete Sciences to give the requisite grasp of simple causation. Studied by themselves the Organic Sciences tend rather to make the ideas of causation cloudy; for the reason that the entanglement of the factors and the contingency of the results is so great that definite relations of antecedents and consequents cannot be established: the two are not presented in such connections as to make the conception of causal action, qualitative and quantitative, sufficiently distinct. There requires, first, the discipline yielded by Physics and Chemistry, to make definite the ideas of forces and actions as necessarily related in their kinds and amounts; and then the study of organic phenomena may be carried on with a clear consciousness that while the processes of causation are so involved as often to be inexplicable, yet there *is* causation, no less necessary and no less exact than causation of simpler kinds.

And now to apply these considerations on mental discipline to our immediate topic. For the effectual study of Sociology there needs a habit of thought generated by the studies of all these sciences; since, as already said, social phenomena involve phenomena of every order.

That there are necessities of relation such as those with which the Abstract Sciences deal, cannot be denied, when it is seen that societies present facts of number and quantity. That the actions of men in society, in all their movements and productive processes, must conform to the laws of the physical forces, is also indisputable. And that every thing thought and felt and done in the course of social life is thought and felt and done in harmony with the laws of individual life, is also a truth—almost a truism, indeed; though one of which few seem conscious.

Culture of the sciences in general, then, is needful; and, above all, culture of the Science of Life. This is more especially requisite, however, because the conceptions of continuity, complexity, and contingency, of causation, as well as the conception of fructifying causation, are conceptions common to it and to the Science of Society. It affords a specially-fit discipline, for the reason that it alone among the sciences produces familiarity with these cardinal ideas—presents the data for them in forms easily grasped, and so prepares the mind for recognizing the data for them in the Social Science, where they are less easily grasped, though no less constantly presented.

The supreme importance of this last kind of culture, however, is not to be adequately shown by this brief statement. For, besides generating habits of thought appropriate to the study of the Social Science, it furnishes the mind with special conceptions which serve as keys to the Social Science. The Science of Life yields to the Science of Society certain great generalizations without which there can be no Science of Society at all. Let us go on to observe the relations of the two.

FOOTPRINTS IN THE ROCKS.

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SEVENTY years ago, a student belonging to Williams College, while holding the plough in his father's field at South Hadley, Massachusetts, turned over a flat slab of sandstone about three feet long. His attention was directed to what seemed to be a row of bird-tracks upon its surface. He had often noticed—as has every intelligent person—the impressions made by the feet of animals in the mud, upon the shores of rivers, lakes, and in the highway. But he had never before seen the imprint of an animal's foot upon the solid rock, and had been taught to believe that the ledges were suddenly called into being by the Almighty without passing through a tedious formative process. Here, however, was a phenomenon not to be explained in accordance with the popular opinion—real footprints in the solid rock—and how came they there?

It was before the days of much geological knowledge, but Pliny Moody exercised a common-sense method of explaining what he saw; for he concluded that these markings were made by some animal in an early period of the earth's history. Nothing was more natural to him than to surmise that they were made during the earliest aqueous deposit of which he had heard—the muddy sediments left by the Noachian Deluge. Hence he pointed out these foot-marks to his friends—the specimen being utilized for a stepping-stone at his front-door—as having been made by Noah's raven when wandering in search of dry land. The slab is still preserved, and the impressions appear to have been made by one of that remarkable group of animals which abounded in New England during the Triassic or New Red Sandstone period.

Thirty-five years later, as Mr. W. W. Draper, of Greenfield, a village thirty miles farther north, was returning home from church, his attention was arrested by the sliding of snow from some large paving-stones leaning against a fence. As he turned his eyes, he saw a row of apparent ornithic impressions on the slab, shown very distinctly on account of the reflection of the sun's rays from a wet surface. A philosophic induction was the result of his observation, and he immediately remarked to his wife: "There are some turkey's tracks made three thousand years ago!"

These two minds, though untutored in scientific lore, each independently of the other, expressed that fundamental generalization of paleontology which has never been set aside, though wondrously amplified and illustrated since that time: that these impressions were made by living animals in immensely remote periods, when the physical geography of the country differed from what it is at present—that is to say, when the existing solid ledges were in the formative process.

Mr. Draper soon communicated his views to his friends, especially to Captain John Wilson. Captain Wilson did the same to Dexter Marsh, and Mr. Marsh to the village physician, Dr. James Deane. All these gentlemen coincided with the theory of Mr. Draper, that the markings were turkey-tracks; but, as none of them were geologists, they felt the need of competent advice. Accordingly, Dr. Deane sent descriptions of the slabs to the State Geologist, the late Prof. Edward Hitchcock, of Amherst, urging him to come and examine them. A similar sketch was sent to the late Prof. Benjamin Silliman, of New Haven, who expressed no opinion about it, but wished Prof. Hitchcock to investigate the subject. As soon as it was convenient, this gentleman went to Greenfield and examined the specimens. His acquaintance with geological literature and methods of investigation apprised him that this new theory, though plausible, must pass through a severe ordeal before it could be established. Not merely was it questionable whether footprints could be preserved for ages, but it was a monstrous assumption—unheard of in geological circles—to talk of birds as a part of the Triassic fauna! Such an announcement could not fail to evolve unanimous disapproval; and, if premature, if published without careful investigation, it might prove to be an egregious blunder, and haunt the unfortunate author through his lifetime.

The scientific investigation of the subject having been thus urgently placed in Prof. Hitchcock's hands by those immediately and remotely interested, he spent the summer of 1835 in studying the characters derived from the progression of animals, whether birds or quadrupeds. Visits were made to all the sandstone-quarries in the Connecticut Valley, to menageries, museums, and libraries, thus insuring the inspection of all slabs exhibiting similar impressions, an examination of the feet of living animals, especially of those most nearly allied to the new forms, and the assurance that nothing similar had ever been found in any part of the world. The result of this protracted investigation indicated the truth of the first surmises—that these impressions were actually made by the feet of birds in the Triassic period. A full account of the discoveries was published in Prof. Silliman's magazine, the *American Journal of Science and Art* for January, 1836. Descriptions were given of seven species of avian impressions, called *Ornithichnites*, or *bird-tracks on stone*. One of them was a foot of gigantic dimensions, not less than sixteen inches long, three times larger than its nearest living representative. It was no wonder that, in these early days, even the father of the science hesitated to admit these monsters into his ichnitic family, yet so exact are the laws of comparative anatomy, and so like the rows of impressions made by living feet were these giants, that a relationship to existing groups could be no longer denied.

A few geologists accepted these doctrines immediately after their promulgation; but most of them, as well as the community in general, doubted whether the preservation of foot-marks were possible, and especially whether they could have been made by birds. Some thought the resemblance was fanciful; others that they were the remains of peculiar marine plants. The public mind, which had no scientific appreciation of the subject, saw abundant opportunity for witticism, and did not spare the shaft of ridicule. The American Association of Geologists and Naturalists at length appointed a committee to investigate the subject, including in the list both the friends and opponents of the new views. They visited Prof. Hitchcock in due time, explored the quarries, examined his specimens, and became convinced unanimously that his views were correct. Their report to the Association states that "the evidence entirely favors the views of Prof. Hitchcock, and they regret that a difference had existed, if they did not feel assured it would lead to greater stability of opinion." This committee consisted of H. D. Rogers, E. Emmons, Lardner Vanuxem, Richard C. Taylor, and T. A. Conrad.

The public generally acquiesced in the truth of this report; they ceased to ridicule, and began to believe that a new chapter in the earth's history had been laid bare for perusal; great popular interest was excited in the foot-marks, and at the present day everybody has heard of the wonderful tracks upon stone in the Connecticut River Valley. The name of their principal expounder, who first published an account of them to the world, and waged a seven years' contest with his compeers and the public on this account, has become indelibly associated with them.

The results of Prof. Hitchcock's researches have been published in two large quarto volumes entitled "The Ichnology of New England." Of other publications, the "Ichnographs" of the Connecticut sandstone are worthy of notice as a monument to the memory of Dr. James Deane, whose early interest in the foot-marks never flagged, and who applied himself earnestly to the study of geology, so that his later writings have become invested with the authority of an able and accurate observer.

Amherst College now possesses the unrivalled collection of ichnites collected by Prof. Hitchcock. They occupy a room 100 feet long and 40 feet wide, and are more than 20,000 in number.

The first scientific publication concerning fossil foot-marks is contained in the Transactions of the Royal Society of Edinburgh in 1828. Six years later, Prof. Kaup described the tracks of the *Cheirotherium, a beast with hands*, upon Triassic sandstones in Germany. The animal must have equalled an ox in size, with hind-feet shaped like the human hand, which were about three times larger than the front-feet. He is generally supposed to have been a batrachian. The earliest description of the American ichnites appeared in 1836.

The Triassic formations on the Atlantic slope are disposed in long and narrow areas. These may correspond with the spaces occupied by estuaries before the deposition of the strata. We may suppose that an arm of the sea extended northerly from Long Island Sound to New Hampshire along the Connecticut Valley, possibly connecting, beneath the Sound and North River, with a similar estuary running southerly to Virginia. If we transport ourselves in imagination to these ancient shores, we shall see that the animals left their hiding-places and were traversing the soft mud laid bare by the ebbing tide, in search of food. The heat of a tropical sun quickly hardens the mud, so that the returning tide, in bringing a fresh deposit of mud, does not wash away the impressions already made on the lower layer, but carefully covers them over. The imprints have, therefore, become a species of mould into which another muddy fluid is poured, and by hardening is made to copy the foot-mark like a plaster cast. Hence, when artificially cleared, no matter how many ages subsequently, the strata will present to view the depressed print below and the cast of the foot above, both as perfect as the respective fineness of the mud and its degree of rapid induration by the sun will permit. This process of deposition may have been repeated, just as it may now be studied, in the Bay of Fundy, till the whole estuary was filled up, partly with fine mud and clay, partly with beds of sand and gravel, all more or less marked by the feet of animals, interspersed with volcanic beds of lava, tufa, and conglomerate, and rare chemical deposits of carbonate of lime, salt, and gypsum.

The *Ichnozoa*, or the animals who made the tracks on stones in Triassic times, may be referred to several prominent divisions of the animal kingdom. The first, and highest in the scale, is a group of five species, remotely allied to marsupials, which, from their osseous remains found in Europe, we know must have flourished in that period. The most characteristic is a five-toed quadruped, about the size of a lion, whose foot is not unlike that of a carnivorous animal. The others had unequal feet, larger behind and smaller in front. The most important groups are those referred to birds, embracing thirty-four species; equally divided between those related to the ostrich family—thick-toed—and those with long, slender toes, like the crane and heron. These are the impressions chiefly relied upon to prove the ornithic character of any of the Ichnozoa, as they show distinctly the phalangeal joints of the toes, like the tracks of the ostrich, turkey, and our common domestic fowls. The feet are invariably trifid, and the number of phalanges corresponds perfectly to that observed in the toes of all living birds, viz., three in the inner, four in the middle, and five in the outer toe, including the claws. The inner phalanges are united to the lower leg-bone abreast of each other, a little back of the middle one, and thus the imprint may also show rounded impressions made by the heel, which have been mistaken for phalangeal markings. This thick-toed group invariably took very long steps, corresponding well with the ordinary gait of their living representatives. One of them, with a foot less than three inches long, had a stride of 25 inches, showing a general structure like that of the waders. Moreover, the entire width of the track-way is scarcely greater than that of each individual foot, indicating a very narrow body, stilted high upon long legs. The smallest of this group may be compared with the living snipe; the largest, having a foot 18 inches long, must have equalled in size the largest of the recently-extinct birds of New Zealand, the *Deinornis giganteus*, 10 feet high. The principal genus is the *Brontozoum* (*the animal giant*); and of the thousands of examples of those yet exhumed, not one shows any features in addition to those described, neither a fourth toe, the trace of a front-foot, nor any indication of a tail. Hence, though suggestions as to their reptilian character are abundant, we shall wait for proof that some distinct reptilian feature is joined to the ornithic, before allowing that the *Brontozoum*, or *Grallator*, were not true birds.

But the next group gives evidences, neither scanty nor ambiguous, to prove the existence of a large number of "ornithic reptiles," or "reptilian birds." This order is now entirely extinct, and was first made known to the world by E. Hitchcock's description of the "ornithoid lizards, or batrachians." He saw that some of the characters were ornithic, and that others were reptilian, so that he was compelled, though reluctantly, to refer them to an altogether new group of life. Since this reference, an abundance of discoveries has confirmed these views; and the name of *Herpetoids* has been suggested for them by Prof. Dana.

The general form of the animal was kangaroo-like, with enormous hind-limbs, a prominent tail, and small front extremities, which were rarely if ever brought to the ground so as to make an impression. The animal may often have walked only upon the trifid hind-feet, showing neither the front-feet, the long shin-bones, nor the caudal appendage. We have seen such rows of trifid impressions, 25 or 30 in number, which might hastily be referred to the feet of birds. But, though the general appearance is ornithic, and the number of phalanges agrees with those of birds, the thirty-first impression reveals a kangaroo-form on all-fours—two small five-toed feet in front, two trifid impressions of larger dimensions at the end of a long heel-mark behind, followed by a heart-shaped print, or a trail, that has come from the caudal appendage. This remarkable quadrupedal display is succeeded by another row of trifid impressions; just as if the animal stopped to rest on his journey, and then resumed his line of march.

Surely no one can doubt the quadrupedal character of this *Anomœpus.* Yet, it was not till after years of discussion and discovery had

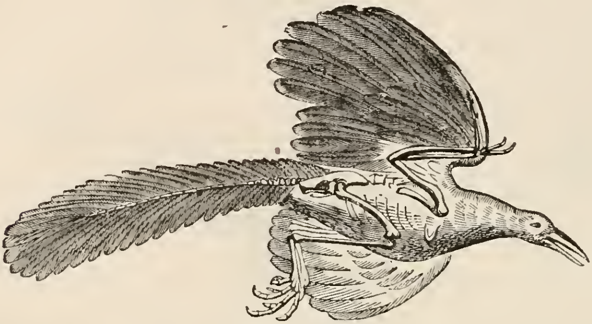
Fig. 1.

Anomœpus Major.

elapsed that his true relationship was appreciated. The first-discovered rows were supposed to be ornithic, and it was these quadrupedal features that led some authors hastily to infer that all the trifid impressions were reptilian, or marsupial. The bipedal rows themselves offer two features distinguishing the most nearly-allied forms from the birds: first, the animals took very short steps; and, secondly, the great width of the track-way indicated a very broad body, probably inferior, in delicacy of organization, to that of birds. To these two invariable characters are commonly added a caudal trail, a fourth toe on an occasional front-foot impression, so that the study of a large suite of specimens will satisfy the most truthful observer that these animals were not birds. The total number of species of this character is 21. One of these equalled the largest *Brontozoum* in size, whose front-foot has not yet been found, though we have indications of a fourth toe behind, and a long, slender tail.

It may not be out of place to allude briefly to the discoveries which have confirmed the existence of the group of ornithic reptiles. The first link in the series was furnished by the discovery of the nearly-complete skeleton of a bird related to the raven in the lithographic stone of the Jurassic series of Bavaria, called the *Archeopteryx.* A feather belonging to this genus was found in 1861, and described with great minuteness by Hermann von Meyer. Shortly afterward, Andreas Wagner described the nearly-complete skeleton of an animal, to which were attached feathers like the one made known by Von Meyer. He called the animal a flying reptile. Prof. Owen, of the British Museum, made a very thorough examination of the same specimen, and perceived that the feathers corresponded with that named by Von Meyer. It seems to differ in only two particulars from ordinary birds: first, there are two fore-fingers, like hooks, projecting from the wings; and, secondly, the tail is shaped like that of the squirrel, with twenty vertebræ ranged in a line, each with a pair of quill-feathers attached. These variations are not sufficiently great to render it necessary to remove the *Archeopteryx* from the bird division, but they indicate in

Fig. 2.



Archeopteryx.

what direction we are to expect a modification of the ornithic type, as it approaches the reptile. And it is in precisely these two respects that the Triassic Herpetoids differ from true birds.

The second link was furnished by the structure of the feet and the ichnites of the *Iguanodon* in England. Both pairs of limbs were terminated by three-toed feet, often of great size. Only two impressions appear, yet Prof. Owen supposes the tracks of the fore-feet were always covered by the hind-feet. The largest of these impressions are 28 inches long and 25 broad, and the stride sometimes reaches 46 inches. This was the largest of all the English terrestrial herbivorous reptiles, and his impressions have been extensively collected near Hastings.

The third link was furnished by the *Hadrosaurus* of New Jersey, the American representative of the *Iguanodon*. He appears to have had the general form of the kangaroo, enormous hind-limbs, terminated by trifid feet; a powerful tail, almost rudimentary anterior extremities, with a skull slightly ornithic, the height of the structure being from 12 to 15 feet. It is singularly like the Ichnozoa *Gigantitherium*. In fact, if we may follow the fashionable creed of the day, it may be said that the New-Jersey *Hadrosaurus* was the lineal descendant of the Massachusetts *Gigantitherium*.

For other links of this series it is only necessary to refer to the late publications of Cope, Huxley, Seely, Owen, Marsh, and other distinguished paleontologists, in which are described nearly a score of kangaroo-like reptiles flourishing, in the later Mesozoic times, in all quarters of the globe. All those new forms present features clearly defining them from both birds on the one hand, and reptiles on the other, so that we are warranted in believing in the existence of genuine birds as well as of ornithic reptiles in ichniferous times.

Fig. 3.

Gigantitherium.

The Triassic period was *par excellence* the Age of Reptiles. Besides the Ichnozoa, the museums teem with specimens of fossil bones of various types of Amphibian, Batrachian, Crocodilian, and Lacertilian forms. We should, therefore, naturally expect that a kangaroo-form of body was not indicative of marsupial structure, but rather a modification of reptilian, in the passage, if we may so speak, of the Lacertian to the Ornithic type.

Twenty-one of the Connecticut ichnites have been referred to the ordinary type of reptiles—the Lacertians—and six to the turtles. Perhaps the number of the former should be increased at the expense of the marsupials and narrow-toed birds. The largest reptile foot is about 15 inches long, three toes in front, curved toward the line of march. It has, besides, a stout thumb, or spur, pointed inwardly. The track-ways of turtles show the trail of the tail, in addition to a pair of feet on both sides.

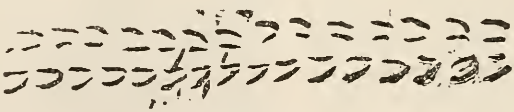
The group of Amphibians, chiefly batrachians, contains several of interest. Prominent among them is the *Otozoum*, a track discovered by Mr. Pliny Moody, the first person in the whole world who exhumed an ichnite, so far as has been determined. The animal had a foot 20 inches long, very broad, perhaps web-footed, embracing not less than a square foot of surface. In shape it resembles the *Cheirotherium*, only it had three fingers instead of four, with a thumb. One species has the thumb recurved, and the other shows it pointed directly forward. The front is about one-third the size of this large hind-foot, and the toes are arranged like those of the front-feet of the Herpetoids. One of the species seems to have had a long, slender tail. This batrachian must have been as large as an elephant, and exceeded in size every other animal among the Ichnozoa. Imagine a frog as large as an elephant, whether announcing the advent of spring by piping, croaking at night in the summer, or taking gigantic leaps after the manner of his modern representatives!

A very important character in the feet of frogs is the possession of pellets, or knobs, instead of claws, at the ends of the toes. These may be observed in the *Otozoum*, and all the other genera of this group. One genus resembles the *Cheirotherium* in form, but not in size, having a foot less than an inch long. None have the remarkably long middle toes on the hind-foot, so characteristic of living frogs.

A small, living salamander has the posterior feet pointing backward; and, as he walks, the toes point away from the head. The track-way, therefore, consists of two parallel rows of footprints, half of each pointing forward and half directed backward. This salamander has its representative ichnozoan in the *Stenodactylus*, not varying essentially in size from it.

One of the most interesting classes of batrachian impressions is called *Batrachoides*. They consist of numerous saucer-shaped hollows an inch in diameter, crowded together so thickly that the original oval outlines have become pentagonal. Not unfrequently these saucers are arranged in lines and squares, because parallel rows of ripple-marks were occupied by the animals in their construction, often covering several square yards of surface.

Fig. 4.



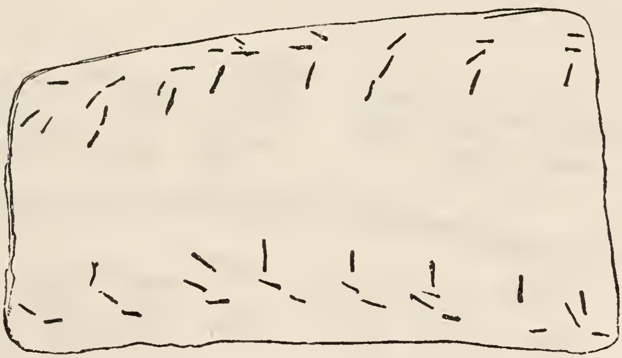
Bifurculipes.

Whether arranged in order or clustered helter-skelter, these impressions cannot be distinguished from the mud-nests made every summer by existing tadpoles. Hence it is natural to suppose that the markings made at the different periods were produced by the same agency; and, as we know the origin of the latter, we may infer how the first came upon the rocks. The chief difficulty in the way of accepting this view lies in the perfect resemblance between them. If this doctrine is received, we must believe in the existence of tadpoles in the carboniferous rocks, because they contain similar relics. Those in the Triassic are remarkably distinct, making most beautiful specimens for the show-case.

The reference of the next group to the class of fishes may excite surprise, for it is commonly supposed that these animals never leave the water for the land. It has been ascertained by naturalists that certain varieties of tropical fish often leave the water, and walk, or rather hobble, on the shore, using their fins for legs. This they can do for days together. They have also been known to climb trees in search of sustenance. Their track-way would be peculiar, consisting of two rows of dots or round impressions, made by the prominent sharp spine of the fin, accompanied by various trails produced by the shorter rays, body, and tail. One species of the *Ichnozoa* has made a trail so much like the markings of these tropical fish that we must believe the *Siluridæ* had other representatives in the Triassic waters. Another impression seems to have been made by an ordinary fish striking his fins against the ridges between ripple-marks in very shallow water.

With considerable hesitation, thirty-four species of *Ichnozoa* may be referred to *insects*. These animals generally have six feet. If attention be paid to the manner in which the common fly walks, it will appear that every foot is brought to the ground, each in a different place, so that every extremity makes a mark. A fly that has been immersed in a colored fluid, and then travels over a sheet of white paper, will leave impressions as distinct as those found upon stone, and the colored track-ways must be our guides to the affinities of the ancient ichnites, like the *Copeza*.

Fig. 5.



Copeza.

Between these ancient and modern impressions it is difficult to find marked differences, except of size. Each displays two rows of impressions in groups of three, the several clusters alternating with one another. Of the three marks or lines in each cluster, the inner is almost at right angles with the line of march, the central and outer point backward, the latter the most.

We may suppose that each group of markings was made by the three feet on each side of the animal, the inner impressions by the front pair of limbs, and the outer by the hindmost. Such groups would be preserved only under the most favorable circumstances. In many species the three pairs of legs might be of the same length, and two or more of the feet might tread upon the same spot, leaving but

Fig. 6.

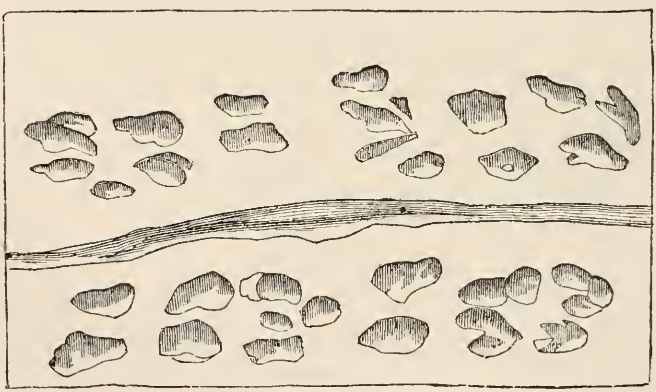
Hamipes.

a single mark. Or the mud may have varied in its capacity for retaining the impressions, so that one or more rows may be wanting. Such cases are common among the *Ichnozoa*, so that track-ways very dissimilar to the unpractised eye are referred to the same species.

No attempt has been made to refer several ichnitic genera to the several orders of insects. With the small information now existing respecting insectean locomotion, such reference would be premature. It is very obvious that the selection must be made from groups frequenting the sea-shore at low tide.

Considering the lightness of these insects, or whatever animals

Fig. 7.



The Prototichnites.

they may have been, it is remarkable that any part of these impressions should have been preserved. Only one good locality of them is known, upon a very fine-grained clayey rock, whose liquidity was sufficient to allow the marks to be made, and yet so solid that the heat of the sun evaporated the bulk of the water between the ebb and flow of a single tide. This locality is at the Lily Pond, Turner's Falls, near Greenfield, Massachusetts.

As might be expected, there was a group of *Crustaceans*, animals who frequent the mud left at low tide. Their impressions have been left on the rocks from the dawn of the Paleozoic age to the very latest period. The famous *Prototichnites* of Canada upon the Potsdam sandstone, so ably described by Logan and Owen, are generally thought to have been made by gigantic representatives of this class, though hardly by the *Pterogotus* form, as suggested by Salter and Woodward, because the latter were exclusively swimming animals. The *Prototichnites* were not represented in the Trias. The forms preserved at Amherst are peculiar, and not to be referred to any special order of Crustacea. One was a giant with a track-way 27 yards wide, and the idea suggested by its inspection is that of an animal with small body stilted high upon very long legs.

Other species of *Ichnozoa* may have been *Annelids*, with their sinuous, fimbriated line of march, *worms*, *mollusks*, with single, double, or treble depressed lines, and various larval forms—whether like those crawling over the surface or making burrows in the mud. A square rod of this Triassic surface will be as thoroughly carved by these various impressions, produced by the lower orders of animal life, as the same surface of the sea-shore in temperate or tropical climes at the present day.

Thus this brief review of the different classes of Triassic *Ichnozoa* shows a natural assemblage, such as might be found associated in maritime districts. The huge birds associated with kangaroo-like forms reminds us immediately of the modern Australian realm, with the cassowaries and the long list of marsupials. Indeed, it would not be strange if the assemblage of life which first showed itself in the American Triassic estuaries had gradually migrated eastward over regions now covered by the Northern Atlantic, pushing farther and farther in each geological era till the *ultima Thule* of Australia is reached, where the modern representatives of the *Ichnozoa* were prevented from further migration by the termination of continental areas. Soon after its occupation, Australia must have been separated from the Asiatic Continent by a partial submergence, so that the peculiar fauna became restricted, and none of the animals could retrace their steps toward the setting sun, even if they desired. It may be, then, that historic Australia represents Triassic New England in its faunal peculiarities—terrestrial, but not maritime, since marine animals cannot so easily be restricted in their migrations or developments.

Besides footprints, other markings on the Connecticut sandstone attract our attention. We observe the marks of rain-drops, ripples of the waves, shrinkage-cracks, broken bubbles arising from marsh-gas, septaria, rarely a shell, a possible echinoderm, coprolites of birds as determined by chemical analysis, a few reptilian bones, bark and cones of gymnosperms, besides other curious marine and terrestrial plants, remain.

The most interesting of these are the rain-drop impressions, particularly as they indicate the formation of the tracks of animals upon a surface not covered by water. Every rain-drop will leave a single round impression. They are preserved most perfectly when it barely sprinkles. In a heavy or long-continued shower so many impressions are made that they coalesce and leave no distinct trace of their existence. They might be said to resemble a chopped sea. None of the latter could be recognized upon the rock, even if they existed; but the sparsely-scattered impressions are abundantly, oftentimes elegantly, preserved.

Furthermore, when rain-drops are blown by the wind, they must fall upon the mud at an acute angle, greater or less in proportion to the force of the current. When a small stream of water is made to fall upon a hard, flat surface, it will be deflected, rising at the same angle, thus giving origin to the philosophical statement that the angle of incidence is equal to the angle of reflection. This principle is only partially exemplified by the Triassic phenomena, as the rain-drop is simply elongated in the direction of the wind. But these features illustrate the force and direction of the wind and the amount of the rainfall, so that we see the weather-cock and the rain-gauge of these ancient times. We find the fact impressed upon the strata in the same locality of a change in the course of the wind, showers, and storms, with, of course, intervals of sunshiny weather. Surely, then, the primitive times witnessed the same alternations of storm and sunshine that prevail at present.

The technical department of the science of Ichnology relates to a discussion of the characters derived from locomotion peculiar to each division of the animal kingdom. Certain distinctions are very obvious, such as the peculiarities of bipedal, quadrupedal, and multipedal locomotion. Bipedal tracks are chiefly of man, birds, and occasionally of the kangaroo-forms. So readily can these be distinguished that definitions are superfluous. The quadrupeds display hand-like feet, as the monkeys, rounded toes and heels like the dog, hoofs either single or cloven, and long, slender toes, few or numerous. Others, like the turtle and lizards, would show two rows of impressions, with short or long steps, and an occasional caudal mark. The lower forms of life would display a great variety of trails, loops, and hops; raised burrows in the mud, or vertical holes, and others of endless diversity. It is unnecessary to specify further the various locomotive characters by which the different groups may be recognized. That such exist may be considered as proved—some of them of very precise application. Not less than thirty different locomotive characters are made use of in the description of the New England ichnitic fauna. Further investigations must add to their number and definiteness, and consequently to the value of ichnological studies.

Cuvier has finely described the definiteness and certainty with which we can infer the character of an animal from its track, though, when he wrote, fossil foot-marks were unknown. "Any one," says he, "who observes merely the print of a cloven hoof, may conclude that it has been left by a ruminant animal, and regard the conclusion as equally certain with any other in physics or morals. Consequently, this single footmark clearly indicates to the observer the forms of the teeth, of all the leg-bones, thighs, shoulders, and of the trunk of the body of the animal which left the mark. It is much surer than all the marks of Zadig."

The contemplation of fossil foot-marks may suggest important moral lessons. To leave their names inscribed on the world's history is a universal desire of mankind. To accomplish this object, various methods have been devised; comfort, health, life, and even moral principle, have been sacrificed, and yet the actor has been unable to crawl into the remotest corner of history. There have been conquerors bathing their limbs in the blood of the slain; kings, who have erected towers, pyramids, and cities; authors, who have composed elaborate and learned treatises; gigantic intellects, who have moulded the characters of nations—and yet no traces of their individual names or memories remain to posterity. All of these may have spurned the reptiles crawling beneath their feet; yet the lower orders of animal life—such as flourished hundreds of thousands of years since, before the surface of the earth was fitted for the residence of man—have left memorials of their passage enduring and indelible.

Those who would benefit their fellow-men need not despair. Those senseless tribes had only dead matter to work upon, and the touch of a hammer may ruthlessly destroy what has endured for ages, and it can never be repaired. But man can influence the living mind, imparting lessons that will outlast, in their influence, both time and fate. Then let all our actions be upright, and we shall thus—

——" departing, leave behind us
Footprints on the sands of time."

THE NATURE AND INFLUENCE OF FOODS.[1]

By EDWARD SMITH, M. D., F. R. S.

BEFORE proceeding to consider the numerous foods which will come under review in the course of this work, it seems desirable to offer a few remarks of a general character on their nature and qualities, and the necessity for them.

As a general definition, it may be stated that a food is a substance

[1] From the introductory chapter of the International Scientific Series, No. III., "On Foods."

which, when introduced into the body, supplies material which renews some structure or maintains some vital process; and it is distinguished from a medicine in that the latter modifies some vital action, but does not supply the material which sustains such action.

This is certainly correct so far as relates to the substances which supply nearly all our nourishment, and which the Germans class under the term *Nahrungsmittel*, but there are certain so-called foods known as *Genussmittel*, which seem to form a connecting link, in that they increase vital actions in a degree far beyond the amount of nutritive material which they supply. They thus resemble certain medicines in their action, but, as they supply a proportion of nutritive material, they should be ranked as foods.

It is essential to the idea of a food that it should support or increase vital actions; while medicines usually lessen, but may increase, some of them.

It is not necessary that a food should yield every kind of material which the body requires, for then one might suffice for the wants of man, but that it fulfils one or more of such requirements, so that by a combination of foods the whole wants of the body may be supplied. Neither is it essential that every food should be decomposed or broken up, and its elements caused to enter into new combinations when forming or maintaining the structures of the body, since there are some which in their nature are identical with parts of the body, and, being introduced, may be incorporated with little or no change.

But there are foods which are more valuable to the body than others, in that they supply a greater number of the substances which it requires, and such are known as compound foods, while others, which supply but one element, or which are incorporated without change, may be termed simple foods. Other foods are more valuable because they are more readily changed into the substance of the body, or act more readily and quickly in sustaining vital actions, and these may be called easily-digested or easily-assimilated foods. Others are preferred because they supply a greater quantity of useful nutriment at a less proportionate cost, and are known as economical foods; and foods varying in flavor are classed as more or less agreeable foods.

Some foods are classed according to the source whence they are derived, as animal and vegetable foods; and others according to the density of their substance, as fluid and solid foods.

There are foods which nourish one part of the body only, and others which sustain one chief vital action, and are called flesh-forming or heat-forming foods, while others combine both qualities.

Besides these larger divisions, there are qualities in foods which permit of further classification, such as those which render them particularly fit for different ages, climates, and seasons, and others which possess a special character, as sweetness, acidity, or bitterness.

There are also effects produced by foods apart from or in addition to those of nutrition, which are not common to all; so that some foods more than others influence the action of the heart, lungs, skin, brain, bowels, or other vital organ, while others have antagonistic qualities, so that one may destroy certain effects of another.

Foods are derived from all the great divisions of Nature and natural products, as earth, water, and air, solids, liquids, and gases; and from substances which are living and organic, or inanimate and inorganic. The popular notion of food as a solid substance derived from animals and vegetables, while comprehensive, is too exclusive, since the water which we drink, the air which we breathe, and certain minerals found in the substance of the earth, are of no less importance as foods.

It is, however, of great interest to note how frequently all these are combined in one food, and how closely united are substances which seem to be widely separated. Thus water and minerals are found in both flesh and vegetables, while one or both of the component parts of the air, viz., oxygen and nitrogen, are distributed through every kind of food. Hence, not only may we add food to food to supply the wants of the body, but we may within certain limits substitute one for another as our appetites or wants demand. The necessity for this in the economy of Nature is evident, for, although a good Providence has given to man an almost infinite number of foods, all are not found everywhere, neither can any man obtain all foods found around him.

Further, there seems to be an indissoluble bond existing between all the sources of food. There are the same classes of elements in flesh as in flour, and the same in animals as in vegetables. The vegetable draws water and minerals from the soil, while it absorbs and incorporates the air in its own growth, and is then eaten to sustain the life of animals, so that animals gain the substances which the vegetable first acquired. But, in completing the circle, the vegetable receives from the animal the air which was thrown out in respiration, and lives and grows upon it, and at length the animal itself, in whole or in part, and the refuse which it daily throws off, become the food of the vegetable. Even the very bones of an animal are by the aid of Nature or man made to increase the growth of vegetables, and really to enter into their structure; and, being again eaten, animals may be said to eat their own bones and live on their own flesh. Hence there is not only an unbroken circle in the production of food from different sources, but even the same food may be shown to be produced from itself. Surely this is an illustration of the fable of the young phœnix arising from the ashes of its parent!

Food is required by the body for two chief purposes, viz., to generate heat and to produce and maintain the structures under the influence of life and exertion. The importance of the latter is the more apparent, since wasting of the body is familiarly associated with decay of life; but the former is so much the more urgent, that, whereas the body may waste for a lengthened period and yet live, it rapidly dies when the source of heat is removed or even greatly lessened.

The production of heat in the body, so wonderful in the process and amount, results only from the chemical combination of the elements of food, whether on the minute scale of the atoms of the several tissues, or on the larger one connected with respiration, and is thence called the combustion of food. As familiar illustrations of the production of heat from chemical change, we may mention that, when cold oil of vitriol and cold water are added together, the mixture becomes so hot that the hand cannot bear it, and the heating of haystacks, and also of barley in the process of malting, is well known. This action in the body is not restricted to changes in one element alone, but proceeds with all; yet it is chiefly due to a combination of three elements, viz., oxygen, hydrogen, and carbon, and requires for its support fat, starch, or sugar, or other digestible food composed of those substances, precisely as coal and wood supply fuel for fire without the body.

This effect is made extremely striking, by Prof. Frankland, in the following table, which shows the amount of heat generated from so small a quantity as ten grains of certain foods during their complete combustion within the body, and the force which scientific calculations have shown to be equivalent to that amount of heat. The original quantity used by Prof. Frankland has been reduced by Dr. Letheby to ten grains, for the convenience of English readers:

No. 1.

FOOD.	In combustion raises lbs. of water 1 degree Fahr.	Which is equal to lifting lbs. 1 foot high.
10 grains of dry flesh	13.12	10,128
" " albumen	12.85	9,920
" " lump-sugar	8.61	6,647
" " arrow-root	10.06	7,766
" " butter	18.68	14,421
" " beef-fat	20.91	16,142

Thus we prove that an ounce of fresh lean meat, if entirely burned in the body, would produce heat sufficient to raise about 70 lbs. of water 1° Fahr., or a gallon of water about 7° Fahr. In like manner, one ounce of fresh butter would produce ten times that amount of heat; but it must be added that, as the combustion which is effected within the body is not always complete, the actual effect is less than that now indicated.

It may thus be shown that the division of foods into the two great classes of flesh-formers and heat-generators is not to be taken too incisively, for while a food is renewing flesh it also produces heat, and while the heat-generating food is acting it may also produce a part of flesh in the form of fat; but, although they are so closely associated in their vital work, the leading characteristic of each kind is so marked as to warrant the classification which Liebig has formulated.

It is understood that the structures of the body are in a state of continual change, so that atoms which are present at one hour may be gone the next, and, when gone, the structures will be so far wasted, unless the process of waste be accompanied by renewal. But the renewing substance must be of the same nature as that wasted, so that bone shall be renewed by bone and flesh by flesh; and hence, while the body is always changing, it is always the same. This is the duty assigned to food—to supply to each part of the body the very same kind of material that is lost by waste.

As foods must have the same composition as the body, or supply such other materials as by vital action may be transformed into the substances of the body, it is desirable to gain a general idea of what these substances are.

The following is a summary statement of the principal materials of which the body is composed:

Flesh in its fresh state contains water, fat, fibrine, albumen, and gelatine, besides compounds of lime, phosphorus, soda, potash, magnesia, silica, and iron, and certain extractives.

Blood has a composition similar in elements to that of flesh.

Bone is composed of cartilage, gelatine, fat, and salts of lime, magnesia, soda, and potash, combined with phosphoric and other acids.

Cartilage consists of chondrine, which is like gelatine in composition, with salts of soda, potash, lime, phosphorus, magnesia, sulphur, and iron.

The brain is composed of water, albumen, fat, phosphoric acid, osmazome, and salts.

The liver consists of water, fat, and albumen, with phosphoric and other acids in conjunction with soda, lime, potash, and iron.

The lungs are formed of a substance resembling gelatine, albumen, a substance analogous to caseine, fibrine, various fatty and organic acids, cholesterine, with salts of soda, and iron and water.

Bile consists of water, fat, resin, sugar, fatty and organic acids, cholesterine, and salts of potash, soda, and iron.

Hence it is requisite that the body should be provided with salts of potash, soda, lime, magnesia, sulphur, iron, and manganese, as well as sulphuric, hydrochloric, phosphoric, and fluoric acids and water; also nearly all the fat which it consumes daily, and probably all the nitrogenous substances which it requires, and which are closely allied in composition, as albumen, fibrine, gelatine, and chondrine. It can produce sugar rapidly and largely, and fat slowly and sparely, from other substances; also lactic, acetic, and various organic acids, and peculiar extractive matters.

So great an array of mysterious substances might well prevent us from feeding ourselves or others if the selection of food depended solely upon our knowledge and judgment; but it is not so, for, independently of the aid derived from our appetites, there is the great advantage of having foods which contain a proportion of nearly all these elements; and combinations of foods have been effected by experience which protect even the most ignorant from evil consequences.

Thus flesh, or the muscular tissue of animals, contains precisely the elements which are required in our flesh-formers, and, only limited by quantity, our heat-generators also; and life may be maintained for very lengthened periods upon that food and water when eaten in large quantities. Seeing, moreover, that the source of flesh in animals which are used as food is vegetables, it follows that vegetables should have the same elements as flesh, and it is a fact of great interest that in vegetables we have foods closely analogous to the flesh of animals. Thus, in addition to water and salts, common to both, there is vegetable jelly, vegetable albumen, vegetable fibrine, and vegetable caseine, all having a composition almost identical with animal albumen, gelatine, chondrine, and caseine.

Hence our appetites and the bountiful provision made for us extend our choice to both the vegetable and animal kingdoms, and it is possible to find vegetable foods on which man could live as long as upon animal food alone. Bread is in vegetable foods that which flesh is in animal foods, and each within itself contains nearly all the elements required for nutrition.

When, however, we bring knowledge of a special kind to the aid of our appetites, we are able to discover both the deficiencies in any given food and the kind of food which would meet them. Thus a knowledge of the requirements of the system and of the available uses of food leads to the proper combinations of food, or to the construction of dietaries.

We have thus placed face to face the requirements of the body and the qualities of the foods to be used to supply them, but it is of very common observation that the effect of the supply is but temporary, and needs renewal at definite periods. Hence we show that the needs of the body are tolerably uniform, while the effect of the supply is temporary, or that both the need and the supply are intermittent. This may be readily represented by showing the line of change in the degree of vital action on the body during the twenty-four hours, as produced by my own investigations, and delineated in the graphic diagrams of the present work.

It is there illustrated that, during the repose of the night, the amount of vital action, as shown by the respiration and pulsation, is low and tolerably uniform, while under the influence of food it is high, and varies during the day extremely, but the general course is such that a large increase takes place after a meal, and a considerable decrease before the following meal. This increase, followed by decrease, being due to the action of food, proves that the influence is temporary, and that after a sufficient interval another supply of food is required.

At the same time it must be allowed that the body is not entirely a passive agent subject to the controlling action of food, for no supply could prevent the vital actions subsiding at night, or make them equal both by night and day.

There is a power inherent in the body which accepts or rejects food as to amount, as well as to quality, and which might at length act through the appetite, and refuse the kind supplied. Moreover, the wants of the body vary from many other well-known influences, and cause an increase or decrease in the vital actions which proceeds *pari passu* with the consumption of the transformed or stored-up food in a degree proportionate to the cause, but such effects are often more rapid and transitory than that of food.

The variations in the requirement for food are induced by age, climate, season, and degree of exertion, and will be more fully discussed in the work on Dietaries; but it may now be desirable to give a glance at some of them.

In reference to age, there can be no doubt that all vital processes, including the action of foods, are greater and more rapid in early, and less and slower in later, than in mature life, and in both the former a more frequent administration of food is necessary. In early life, moreover, there is the important function of growth, which demands a large and more frequent supply of food, not only for daily wants, but to promote a due increase in the bulk of the structures of the body. I have also shown that the season of the year has also a decided influence over the vital actions, so that they are the greatest in the spring and the least at the end of summer.

The action of climate is similar to that of season, and shows that the vital actions are greater in cold than in hot climates, and in the uplands than in close valleys.

The influence of exertion over vital changes is immediate and proportionate, while the subsidence with the rest is less rapid than the increase. The following table of experiments upon myself shows the proportionate effect of exertion of varying degrees on the basis of the increased volume of air inspired:

No. 6.

The lying posture	being 1
The sitting posture	is 1.18
Reading aloud or singing	" 1.26
The standing posture	" 1.33
Railway travelling in the 1st class	" 1.40
" " " 2d class	" 1.5
" " upon the engine, at 20 to 30 miles per hour .	" 1.52
" " " " 50 to 60 " "	" 1.55
" " in the 3d class	" 1.58
" " upon the engine, average of all speeds .	" 1.58
" " " " at 40 to 50 miles per hour .	" 1.61
" " " " 30 to 40 " "	" 1.64

Walking in the sea	is	1.65
" on land at 1 mile per hour	"	1.9
Riding on horseback at the walking pace	"	2.2
Walking at 2 miles per hour	"	2.76
Riding on horseback at the cantering pace	"	3.16
Walking at 3 miles per hour	"	3.22
Riding moderately	"	3.33
Descending steps at 640 yards perpendicular per hour	"	3.43
Walking at 3 miles per hour and carrying 34 lbs.	"	3.5
" " " " 62 lbs.	"	3.84
Riding on horseback at the trotting pace	"	4.05
Swimming at good speed	"	4.33
Ascending steps at 640 yards perpendicular per hour	"	4.4
Walking at 3 miles per hour and carrying 118 lbs.	"	4.75
" 4 miles per hour	"	5.0
The tread-wheel, ascending 45 steps per minute	"	5.5
Running at 6 miles per hour	"	7.0

Another table, from the same series of experiments, illustrates the same effect on the basis of the amount of carbonic acid evolved by respiration per minute:

No. 7.

In profound sleep, lying posture	4.5	grains.
In light sleep, "	4.99	"
Scarcely awake, $1\frac{1}{2}$ A. M.	5.7	"
" " $2\frac{1}{2}$ "	5.94	"
" " $6\frac{1}{4}$ "	6.1	"
Walking at 2 miles per hour	18.1	"
" 3 " "	25.83	"
Tread-wheel, ascending 28.15 feet per minute	43.36	"

Thus it is possible that the amount of vital change proceeding in the body may be ten times greater in one state than in another, and it follows that a proportionate quantity of food will be required to sustain it.

LUNAR TEMPERATURES.

POETS have so long sung of the cold, chaste Moon, pallid with weariness of her long watch upon the Earth (according to the image used alike by Wordsworth and Shelley), that it seems strange to learn from science that the full moon is so intensely hot that no creature known to us could long endure contact with her heated surface. Such is the latest news which science has brought us respecting our satellite. The news is not altogether unexpected; in fact, reasoning had shown, long before the fact had been demonstrated, that it must be so. The astronomer knows that the surface of the moon is exposed during the long lunar day, lasting a fortnight of our terrestrial time, to the rays of a sun as powerful as that which gives us our daily heat.

Without an atmosphere to temper the sun's heat as ours does—not, indeed, by impeding the passage of the solar rays, but by bearing aloft the cloud-veil which the sun raises from our oceans—the moon's surface must become intensely hot long before the middle of the lunar day. Undoubtedly the want of an atmosphere causes the moon's heat to be rapidly radiated away into space. It is our atmosphere which causes a steady heat to prevail on our earth. And at the summits of lofty mountains, where the atmosphere is rare, although the mid-day heat is intense, yet so rapidly does the heat pass away that snow crowns forever the mountain-heights. Yet, although the moon's heat must pass away even more rapidly, this does not prevent the heating of the moon's actual surface, any more than the rarity of the air prevents the Alpine traveller from feeling the action of the sun's direct heat even when the air in shadow is icily cold. Accordingly, Sir John Herschel long since pointed out that the moon's surface must be heated at lunar mid-day—or rather, at the time of lunar mid-heat, corresponding to about two o'clock in our afternoon—to a degree probably surpassing the heat of boiling water.

Such, in point of fact, has now been proved to be the case. The Earl of Rosse has shown, by experiments which need not here be described, that the moon not only reflects heat to the earth (which, of course, must be the case), but that she gives out heat by which she has been herself warmed. The distinction may not perhaps appear clear at first sight to every reader, but it may easily be explained and illustrated. If, on a bright summer's day, we take a piece of smooth, but not too well polished, metal, and by means of it reflect the sun's light upon the face, a sensation of heat will be experienced; this is reflected sun-heat: but if we wait while so holding the metal until the plate has become quite hot under the solar rays, we shall recognize a sensation of heat from the mere proximity of the plate to the face, even when the plate is so held as not to reflect sun-heat. We can in succession try—first, reflected heat alone, before the metal has grown hot; next, the heat which the metal gives out of itself when warmed by the sun's rays; and, lastly, the two kinds of heat together, when the metal is caused to reflect sun-heat, and also (being held near the face) to give out a sensible quantity of its own warmth. What Lord Rosse has done has been to show that the full moon sends earthward both kinds of heat; she reflects solar heat just as she reflects solar light, and she also gives out the heat by which her own surface has been warmed.

It may perhaps occur to the reader to inquire how much heat we actually obtain from the full moon. There is a simple way of viewing the matter. If the full moon were exactly as hot as boiling water, we should receive from her just as much heat (leaving the effect of our atmosphere out of account) as we should receive from a small globe as hot as boiling water, and at such a distance as to *look* just as large as the moon does. Or a disk of metal would serve equally well. Now, the experiment may be easily tried. A bronze halfpenny is exactly one inch in diameter, and as the moon's average distance is about 111 times her own diameter, a halfpenny at a distance of 111 inches, or three yards and three inches, looks just as large as the moon. Now let a halfpenny be put in boiling water for a while, so that it becomes as hot as the water; then that coin taken quickly and set three yards from the observer will give out, for the few moments that its heat remains appreciably that of boiling water, as much heat to the observer as he receives from the full moon supposed to be as hot as boiling water. Or a globe of thin metal, one inch in diameter and full of water at boiling-heat, would serve as a more constant artificial moon in respect of heat-supply. It need not be thought remarkable, then, if the heat given out by the full moon is not easily measured, or even recognized. Imagine how little the cold of a winter's day would be relieved by the presence, in a room no otherwise warmed, of a one-inch globe of boiling water, three yards away! And, by-the-way, we are here reminded of an estimate by Prof. C. B. Smyth, resulting from observations made on the moon's heat during his Teneriffe experiments. He found the heat equal to that emitted by the hand at a distance of three feet.

But, after all, the most interesting results flowing from the recent researches are those which relate to the moon herself. We cannot but speculate on the condition of a world so strangely circumstanced that a cold more bitter than that of our arctic nights alternates with a heat exceeding that of boiling water. It is strange to think that the calm-looking moon is exposed to such extraordinary vicissitudes. There can scarcely be life in any part of the moon—unless it be underground life, like that of the Modoc Indians (we commend this idea specially to the more ardent advocates of Brewsterian ideas respecting other worlds than ours). And yet there must be a singularly active mechanical process at work in yonder orb. The moon's substance must expand and contract marvellously as the alternate waves of heat and cold pass over it. The material of that crater-covered surface must be positively crumbling away under the effects of these expansions and contractions. The most plastic terrestrial substances could not long endure such processes, and it seems altogether unlikely that any part of the moon's crust is at all plastic. Can we wonder if, from time to time, astronomers tell us of apparent changes in the moon—a wall sinking here, or a crater vanishing elsewhere? The wonder rather is, that the steep and lofty lunar mountains have not been shaken long since to their very foundations.

Our moon presents, in fact, a strange problem for our investigation. It is gratifying to us terrestrials to regard her as a mere satellite of the earth, but in reality she deserves rather to be regarded as companion planet. She follows a path round the sun which so nearly resembles that pursued by the earth, in shape as well as in extent, that, if the two paths were traced down on a quarto sheet, it would not be easy to distinguish one from the other. Our earth is simply the largest, while the moon is the smallest of that inner family of worlds over which the sun bears special sway, nor does Mercury exceed the moon to so great a degree in mass and in volume as the earth or Venus exceeds Mercury. Yet the moon, with her surface of 14,000,000 square miles, seems to be beyond a doubt a mere desert waste, without air or water, exposed to alternations of heat and cold which no living creature we are acquainted with could endure; and notwithstanding her position as an important member of the solar system, as well as the undoubted fact that in her motions she obeys the sun in preference to the earth, she has nevertheless been so far coerced by the earth's influence as to be compelled to turn always the same face toward her larger companion orb, so that not a ray from the earth ever falls upon fully 5,000,000 square miles of the farther lunar hemisphere. A waste of matter here, we might say, and a waste of all the energy which is represented by the moon's motions, did we not remember that we can see but a little way into the plan of Creation, and that what appears to us waste may in reality be an essential and important part of the great scheme of Nature.—*Spectator.*

THE PROBLEMS OF THE DEEP SEA.

By Prof. T. H. HUXLEY, LL. D., F. R. S.

ON the 21st of December, 1872, H. M. S. Challenger, an eighteen-gun corvette, of 2,000 tons burden, sailed from Portsmouth harbor for a three, or perhaps four, years' cruise. No man-of war ever left that famous port before with so singular an equipment. Two of the eighteen sixty-eight pounders of the Challenger's armament remained to enable her to speak with effect to sea-rovers, haply devoid of any respect for science, in the remote seas for which she is bound; but the main-deck was, for the most part, stripped of its warlike gear, and fitted up with physical, chemical, and biological laboratories; photography had its dark cabin; while apparatus for dredging, trawling, and sounding; for photometers and for thermometers, filled the space formerly occupied by guns and gun-tackle, pistols and cutlasses.

The crew of the Challenger match her fittings. Captain Nares, his officers and men, are ready to look after the interests of hydrography, work the ship, and, if need be, fight her as seamen should; while there is a staff of scientific civilians, under the general direction of Dr. Wyville Thomson, F. R. S. (Professor of Natural History in Edinburgh University by rights, but at present detached for duty *in partibus*), whose business it is to turn all the wonderfully-packed stores of appliances to account, and to accumulate, before the ship returns to England, such additions to natural knowledge as shall justify the labor and cost involved in the fitting out and maintenance of the expedition.

Under the able and zealous superintendence of the hydrographer, Admiral Richards, every precaution which experience and forethought could devise has been taken to provide the expedition with the material conditions of success; and it would seem as if nothing short of wreck or pestilence, both most improbable contingencies, could prevent the Challenger from doing splendid work, and opening up a new era in the history of scientific voyages.

The dispatch of this expedition is the culmination of a series of such enterprises, gradually increasing in magnitude and importance, which the Admiralty, greatly to its credit, has carried out for some years past; and the history of which is given by Dr. Wyville Thomson in the beautifully-illustrated volume entitled "The Depths of the Sea," published since his departure:

"In the spring of the year 1868, my friend Dr. W. B. Carpenter, at that time one of the vice-presidents of the Royal Society, was with me in Ireland, where we were working out together the structure and development of the Crinoids. I had long previously had a profound conviction that the land of promise for the naturalist, the only remaining region where there were endless novelties of extraordinary interest ready to the hand which had the means of gathering them, was the bottom of the deep sea. I had even had a glimpse of some of these treasures, for I had seen, the year before, with Prof. Sars, the forms which I have already mentioned, dredged by his son at a depth of 300 to 400 fathoms off the Loffoden Islands. I propounded my views to my fellow-laborer, and we discussed the subject many times over our microscopes. I strongly urged Dr. Carpenter to use his influence at headquarters to induce the Admiralty, probably through the Council of the Royal Society, to give us the use of a vessel properly fitted with a dredging-gear and all necessary scientific apparatus, that many heavy questions as to the state of things in the depths of the ocean, which were still in a state of uncertainty, might be definitely settled. After full consideration, Dr. Carpenter promised his hearty coöperation, and we agreed that I should write to him on his return to London, indicating generally the results which I anticipated, and sketching out what I conceived to be a promising line of inquiry. The Council of the Royal Society warmly supported the proposal; and I give here in chronological order the short and eminently satisfactory correspondence which led to the Admiralty placing at the disposal of Dr. Carpenter and myself the gunboat Lightning, under the command of Staff-Commander May, R. N., in the summer of 1868, for a trial cruise to the north of Scotland, and afterward to the much wider surveys in H. M. S. Porcupine, Captain Calver, R. N., which were made with the additional association of Mr. Gwyn Jeffreys, in the summers of the years 1869 and 1870."[1]

[1] "The Depths of the Sea," pp. 49, 50.

Plain men may be puzzled to understand why Dr. Wyville Thomson, not being a cynic, should relegate the "Land of Promise" to the bottom of the deep sea; they may still more wonder what manner of "milk and honey" the Challenger expects to find; and their perplexity may well rise to its maximum, when they seek to divine the manner in which that milk and honey are to be got out of so inaccessible a Canaan. I will, therefore, endeavor to give some answer to these questions in an order the reverse of that in which I have stated them.

Apart from hooks, and lines, and ordinary nets, fishermen have, from time immemorial, made use of two kinds of implements for getting at sea-creatures which live beyond tide-marks—these are the "dredge" and the "trawl." The dredge is used by oyster-fishermen. Imagine a large bag, the mouth of which has the shape of an elongated parallelogram, and is fastened to an iron frame of the same shape, the two long sides of this rim being fashioned into scrapers. Chains attach the ends of the frame to a stout rope, so that when the bag is dragged along by the rope, the edge of one of the scrapers rests on the ground, and scrapes whatever it touches into the bag. The oyster-dredger takes one of these machines in his boat, and when he has reached the oyster-bed the dredge is tossed overboard; as soon as it has sunk to the bottom, the rope is paid out sufficiently to prevent it from pulling the dredge directly upward, and is then made fast while the boat goes ahead. The dredge is thus dragged along and scrapes oysters and other sea-animals and plants, stones, and mud into the bag. When the dredger judges it to be full he hauls it up, picks out the oysters, throws the rest overboard, and begins again.

Dredging in shallow water, say ten to twenty fathoms, is an easy operation enough; but the deeper the dredger goes, the heavier must be his vessel, and the stouter his tackle, while the operation of hauling up becomes more and more laborious. Dredging in 150 fathoms is very hard work, if it has to be carried on by manual labor; but by the use of the donkey-engine to supply power,[1] and of the contrivances known as "accumulators," to diminish the risk of snapping the dredge-rope by the rolling and pitching of the vessel, the dredge has been worked deeper and deeper, until at last, on the 22d of July, 1869, H. M. S. Porcupine being in the Bay of Biscay, Captain Calver, her commander, performed the unprecedented feat of dredging in 2,435 fathoms, or 14,610 feet, a depth nearly equal to the height of Mont Blanc. The dredge "was rapidly hauled on deck at one o'clock in the morning of the 23d, after an absence of 7¼ hours, and a journey of

[1] The emotional side of the scientific nature has its singularities. Many persons will call to mind a certain philosopher's tenderness over his watch—"the little creature"—which was so singularly lost and found again. But Dr. Wyville Thomson surpasses the owner of the watch in his loving-kindness toward a donkey-engine. "This little engine was the comfort of our lives. Once or twice it was overstrained, and then we pitied the willing little thing, panting like an overtaxed horse."

upward of eight statute miles," with a hundred-weight and a half of solid contents.

The trawl is a sort of net for catching those fish which habitually live at the bottom of the sea, such as soles, plaice, turbot, and gurnett. The mouth of the net may be thirty or forty feet wide, and one edge of its mouth is fastened to a beam of wood of the same length. The two ends of the beam are supported by curved pieces of iron, which raise the beam and the edge of the net which is fastened to it, for a short distance, while the other edge of the mouth of the net trails upon the ground. The closed end of the net has the form of a great pouch; and, as the beam is dragged along, the fish, roused from the bottom by the sweeping of the net, readily pass into its mouth and accumulate in the pouch at its end. After drifting with the tide for six or seven hours the trawl is hauled up, the marketable fish are picked out, the others thrown away, and the trawl sent overboard for another operation.

More than a thousand sail of well-found trawlers are constantly engaged in sweeping the seas around our coast in this way, and it is to them that we owe a very large proportion of our supply of fish. The difficulty of trawling, like that of dredging, rapidly increases with the depth at which the operation is performed; and, until the other day, it is probable that trawling at so great a depth as 100 fathoms was something unheard of. But the first news from the Challenger opens up new possibilities for the trawl.

Dr. Wyville Thomson writes (*Nature*, March 20, 1873):

"For the first two or three hauls in very deep water off the coast of Portugal, the dredge came up filled with the usual 'Atlantic ooze,' tenacious and uniform throughout, and the work of hours, in sifting, gave the very smallest possible result. We were extremely anxious to get some idea of the general character of the Fauna, and particularly of the distribution of the higher groups; and, after various suggestions for modification of the dredge, it was proposed to try the ordinary trawl. We had a compact trawl, with a 15-feet beam, on board, and we sent it down off Cape St. Vincent at a depth of 600 fathoms. The experiment looked hazardous, but, to our great satisfaction, the trawl came up all right, and contained, with many of the larger invertebrata, several fishes. . . . After the first attempt we tried the trawl several times at depths of 1,090, 1,525, and, finally, 2,125 fathoms, and always with success."

To the coral-fishers of the Mediterranean, who seek the precious red coral, which grows firmly fixed to rocks at a depth of sixty to eighty fathoms, both the dredge and the trawl would be useless. They, therefore, have recourse to a sort of frame, to which are fastened long bundles of loosely-netted hempen cord, and which is lowered by a rope to the depth at which the hempen cords can sweep over the surface of the rocks and break off the coral, which is brought up entangled in the cords. A similar contrivance has arisen out of the necessities of deep-sea exploration.

In the course of the dredging of the Porcupine, it was frequently found that, while few objects of interest were brought up within the dredge, many living creatures came up sticking to the outside of the dredge-bag, and even to the first few fathoms of the dredge-rope. The mouth of the dredge doubtless rapidly filled with mud, and thus the things it should have brought up were shut out. To remedy this inconvenience Captain Calver devised an arrangement not unlike that employed by the coral-fishers. He fastened half a dozen swabs, such as are used for drying decks, to the dredge. A swab is something like what a birch-broom would be if its twigs were made of long, coarse hempen yarns. These dragged along after the dredge over the surface of the mud, and entangled the creatures living there—multitudes of which, twisted up in the strands of the swabs, were brought to the surface with the dredge. A further improvement was made by attaching a long iron bar to the bottom of the dredge-bag, and fastening large bunches of teased-out hemp to the end of this bar. These "tangles" brought up immense quantities of such animals as have long arms, or spines, or prominences which readily become caught in the hemp, but they are very destructive to the fragile organisms which they imprison; and, now that the trawl can be successfully worked at the greatest depths, it may be expected to supersede them; at least, wherever the ground is soft enough to permit of trawling.

It is obvious that between the dredge, the trawl, and the tangles, there is little chance for any organism, except such as are able to burrow rapidly, to remain safely at the bottom of any part of the sea which the Challenger undertakes to explore. And, for the first time in the history of scientific exploration, we have a fair chance of learning what the population of the depths of the sea is like in the most widely-different parts of the world.

And now arises the next question. The means of exploration being fairly adequate, what forms of life may be looked for at these vast depths?

The systematic study of the Distribution of living beings is the most modern branch of Biological Science, and came into existence long after Morphology and Physiology had attained a considerable development. This naturally does not imply that, from the time men began to observe natural phenomena, they were ignorant of the fact that the animals and plants of one part of the world are different from those in other regions; or that those of the hills are different from those of the plains in the same region; or, finally, that some marine creatures are found only in the shallows, while others inhabit the deeps. Nevertheless, it was only after the discovery of America that the attention of naturalists was powerfully drawn to the wonderful differences between the animal population of the central and southern parts of the New World and that of those parts of the Old World which lie under the same parallels of latitude. So far back as 1667 Abraham

Mylius, in his treatise "*De Animalium origine et migratione populorum*," argues that, since there are innumerable species of animals in America which do not exist elsewhere, they must have been made and placed there by the Deity: Buffon no less forcibly insists upon the difference between the Faunæ of the Old and New World. But the first attempt to gather facts of this order into a whole, and to coördinate them into a series of generalizations, or laws of Geographical Distribution, is not a century old, and is contained in the "Specimen Zoologiæ Geographicæ Quadrupedum Domicilia et Migrationes sistens," published, in 1777, by the learned Brunswick professor, Eberhard Zimmermann, who illustrates his work by what he calls a "Tabula Zoographica," which is the oldest distributional map known to me.

In regard to matters of fact, Zimmermann's chief aim is to show that, among terrestrial mammals, some occur all over the world, while others are restricted to particular areas of greater or smaller extent; and that the abundance of species follows temperature, being greatest in warm and least in cold climates. But marine animals, he thinks, obey no such law. The Arctic and Atlantic Seas, he says, are as full of fishes and other animals as those of the tropics. It is, therefore, clear that cold does not affect the dwellers in the sea as it does land animals, and that this must be the case follows from the fact that sea-water, "propter varias quas continet bituminis spiritusque particulas," freezes with much more difficulty than fresh water. On the other hand, the heat of the Equatorial sun penetrates but a short distance below the surface of the ocean. Moreover, according to Zimmermann, the incessant disturbance of the mass of the sea, by winds and tides, so mixes up the warm and the cold that life is evenly diffused and abundant throughout the ocean.

In 1810, Risso, in his work on the Ichthyology of Nice, laid the foundation of what has since been termed "bathymetrical" distribution, or distribution in depth, by showing that regions of the sea-bottom of different depths could be distinguished by the fishes which inhabit them. There was the *littoral region* between tide-marks with its sand-eels, pipe-fishes, and blennies; the *sea-weed region*, extending from low water-mark to a depth of 450 feet, with its wrasses, rays, and flat-fish; and the *deep-sea region*, from 450 feet to 1,500 feet or more, with its file-fish, sharks, gurnards, cod, and sword-fish.

More than twenty years later, MM. Audouin and Milne Edwards carried out the principle of distinguishing the Faunæ of different zones of depth much more minutely, in their "Recherches pour servir à l'Histoire Naturelle du Littoral de la France," published in 1832.

They divide the area included between high-water mark and low-water mark of spring tides (which is very extensive, on account of the great rise and fall of the tide on the Normandy coast about St. Malo, where the observations were made) into four zones, each characterized by its peculiar invertebrate inhabitants. Beyond the fourth region they distinguish a fifth, which is never uncovered, and is inhabited by oysters, scallops, and large starfishes and other animals. Beyond this they seem to think that animal life is absent.[1]

Audouin and Milne Edwards were the first to see the importance of the bearing of a knowledge of the manner in which marine animals are distributed in depth, on geology. They suggest that, by this means, it will be possible to judge whether a fossiliferous stratum was formed upon the shore of an ancient sea, and even to determine whether it was deposited in shallower or deeper water on that shore; the association of shells or animals which live in different zones of depth will prove that the shells have been transported into the position in which they are found; while, on the other hand, the absence of shells in a deposit will not justify the conclusion that the waters in which it was formed were devoid of animal inhabitants, inasmuch as they might have been only too deep for habitation.

The new line of investigation thus opened by the French naturalists was followed up by the Norwegian, Sars, in 1835, by Edward Forbes, in our own country, in 1840,[2] and by Œrsted, in Denmark, a few years later. The genius of Forbes, combined with his extensive knowledge of botany, invertebrate zoology, and geology, enabled him to do more than any of his compeers in bringing the importance of distribution in depth into notice; and his researches in the Ægean Sea, and still more his remarkable paper "On the Geological Relations of the Existing Fauna and Flora of the British Isles," published in 1846, in the first volume of the "Memoirs of the Geological Survey of Great Britain," attracted universal attention.

On the coasts of the British Islands, Forbes distinguishes four zones or regions, the Littoral (between tide-marks), the Laminarian (between low-water mark and 15 fathoms), the Coralline (from 15 to 50 fathoms), and the Deep sea or Coral region (from 50 fathoms to beyond 100 fathoms). But, in the deeper waters of the Ægean Sea, between the shore and a depth of 300 fathoms, Forbes was able to make out

[1] "Enfin plus bas encore, c'est-à-dire alors loin des côtes, le fond des eaux ne paraît plus être habité, du moins dans nos mers, par aucun de ces animaux" (l. c., tome i., p. 237). The "ces animaux" leaves the meaning of the authors doubtful.

[2] In the paper in the "Memoirs of the Survey" cited farther on, Forbes writes:

"In an essay 'On the Association of Mollusca on the British Coasts, considered with reference to Pleistocene Geology,' printed in the *Edinburgh Academic Annual* for 1840, I described the mollusca, as distributed on our shores and seas, in four great zones or regions, usually denominated 'The Littoral Zone,' 'The region of Laminariæ,' 'The region of Corallines,' and 'The region of Corals.' An extensive series of researches, chiefly conducted by the members of the committee appointed by the British Association to investigate the marine geology of Britain by means of the dredge, have not invalidated this classification, and the researches of Prof. Lovén, in the Norwegian and Lapland Seas, have borne out their correctness. The first two of the regions above mentioned had been previously noticed by Lamouroux, in his account of the distribution (vertically) of sea-weeds, by Audouin and Milne Edwards in their 'Observations on the Natural History of the Coast of France,' and by Sars in the preface to his 'Beskrivelser og Jagttagelser.'"

no fewer than eight zones of life, in the course of which the number and variety of forms gradually diminished; until, beyond 300 fathoms, life disappeared altogther. Hence it appeared as if descent in the sea had much the same effect on life as ascent on land. Recent investigations appear to show that Forbes was right enough in his classification of the facts of distribution in depth as they are to be observed in the Ægean; and though, at the time he wrote, one or two observations were extant which might have warned him not to generalize too extensively from his Ægean experience, his own dredging-work was so much more extensive and systematic than that of any other naturalist, that it is not wonderful he should have felt justified in building upon it. Nevertheless, so far as the limit of the range of life in depth goes, Forbes's conclusion has been completely negatived, and the greatest depths yet attained show not even an approach to a "zero of life:"

"During the several cruises of H. M. ships Lightning and Porcupine in the years 1868, 1869, and 1870," says Dr. Wyville Thomson, "fifty-seven hauls of the dredge were taken in the Atlantic at depths beyond 500 fathoms, and sixteen at depths beyond 1,000 fathoms, and, in all cases, life was abundant. In 1869 we took two casts in depths greater than 2,000 fathoms. In both of these life was abundant; and with the deepest cast, 2,435 fathoms, off the mouth of the Bay of Biscay, we took living, well-marked, and characteristic examples of all the five invertebrate sub-kingdoms. And thus the question of the existence of abundant animal life at the bottom of the sea has been finally settled and for all depths, for there is no reason to suppose that the depth anywhere exceeds between three and four thousand fathoms; and, if there be nothing in the conditions of a depth of 2,500 fathoms to prevent the full development of a varied Fauna, it is impossible to suppose that even an additional thousand fathoms would make any great difference." [1]

As Dr. Wyville Thomson's recent letter, cited above, shows, the use of the trawl, at great depths, has brought to light a still greater diversity of life. Fishes came up from a depth of 600 to more than 1,000 fathoms, all "in a peculiar condition from the expansion of the air contained in their bodies. On this relief from the extreme pressure, their eyes, especially, had a singular appearance, protruding like great globes from their heads." Bivalve and univalve mollusca seem to be rare at the greatest depths; but star-fishes, sea-urchins, and other echinoderms, zoophytes, sponges, and protozoa, abound.

It is obvious that the Challenger has the privilege of opening a new chapter in the history of the living world. She cannot send down her dredges and her trawls into these virgin depths of the great ocean

[1] "The Depths of the Sea," p. 30. Results of a similar kind, obtained by previous observers, are stated at length in the sixth chapter, pp. 267–280. The dredgings carried out by Count Pourtales, under the authority of Prof. Peirce, the Superintendent of the United States Coast Survey, in the years 1867, 1868, and 1869, are particularly noteworthy, and it is probably not too much to say, in the words of Prof. Agassiz, "that we owe to the coast survey the first broad and comprehensive basis for an exploration of the sea-bottom on a large scale, opening a new era in zoological and geological research."

without bringing up a discovery. Even though the thing itself may be neither "rich nor rare," the fact that it came from that depth, in that particular latitude and longitude, will be a new fact in distribution, and, as such, have a certain importance.

But it may be confidently assumed that the things brought up will very frequently be zoological novelties; or, better still, zoological antiquities, which in the tranquil and little-changed depths of the ocean have escaped the causes of destruction at work in the shallows, and represent the predominant population of a past age.

It has been seen that Audouin and Milne Edwards foresaw the general influence of the study of distribution in depth upon the interpretation of geological phenomena. Forbes connected the two orders of inquiry still more closely; and, in the thoughtful essay "On the Connection between the Distribution of the Existing Fauna and Flora of the British Isles, and the Geological Changes which have affected their Area, especially during the Epoch of the Northern Drift," to which reference has already been made, he put forth a most pregnant suggestion.

In certain parts of the sea-bottom in the immediate vicinity of the British Islands, as in the Clyde district, among the Hebrides, in the Moray Firth, and in the German Ocean, there are depressed areæ, forming a kind of submarine valleys, the centres of which are from 80 to 100 fathoms, or more, deep. These depressions are inhabited by assemblages of marine animals, which differ from those found over the adjacent and shallower region, and resemble those which are met with much farther north, on the Norwegian coast. Forbes called these Scandinavian detachments "northern outliers."

How did these isolated patches of a northern population get into these deep places? To explain the mystery, Forbes called to mind the fact that, in the epoch which immediately preceded the present, the climate was much colder (whence the name of "glacial epoch" applied to it); and that the shells which are found fossil, or sub-fossil, in deposits of that age are precisely such as are now to be met with only in the Scandinavian or still more arctic regions. Undoubtedly, during the glacial epoch, the general population of our seas had, universally, the northern aspect which is now presented only by the "northern outliers," just as the vegetation of the land, down to the sea-level, had the northern character which is, at present, exhibited only by the plants which live on the tops of our mountains. But, as the glacial epoch passed away, and the present climatal conditions were developed, the northern plants were able to maintain themselves only on the bleak heights, on which southern forms could not compete with them. And, in like manner, Forbes suggested that, after the glacial epoch, the northern animals then inhabiting the sea became restricted to the deeps in which they could hold their own against invaders from the south, better fitted than they to flourish in the warmer waters of the shallows. Thus depth in the sea corresponded, in its effect upon distribution, to height on the land.

The same idea is applied to the explanation of a similar anomaly in the Fauna of the Ægean:

"In the deepest of the regions of depth of the Ægean, the representation of a northern Fauna is maintained, partly by identical and partly by representative forms. . . . The presence of the latter is essentially due to the law (of representation of parallels of latitude by zones of depth), while that of the former species depended on their transmission from their parent seas during a former epoch and subsequent isolation. That epoch was doubtless the newer Pliocene or Glacial Era, when the *Mya truncata* and other northern forms now extinct in the Mediterranean, and found fossil in the Sicilian tertiaries, ranged into that sea. The changes which there destroyed the *shallow-water* glacial forms, did not affect those living in the depths, and which still survive." [1]

The conception that the inhabitants of local depressions of the sea-bottom might be a remnant of the ancient population of the area, which had held their own in these deep fastnesses against an invading Fauna, as Britons and Gaels have held out in Wales and in Scotland against encroaching Teutons, thus broached by Forbes, received a wider application than Forbes had dreamed of when the sounding machine first brought up specimens of the mud of the deep sea. As I have pointed out elsewhere,[2] it at once became obvious that the calcareous, sticky mud of the Atlantic was made up, in the main, of shells of *Globigerina* and other *Foraminifera*, identical with those of which the true chalk is composed, and the identity extended even to the presence of those singular bodies, the coccoliths and coccospheres, the true nature of which is not yet made out. Here, then, were organisms, as old as the Cretaceous epoch, still alive, and doing their work of rock-making at the bottom of existing seas. What if *Globigerina* and the coccoliths should not be the only survivors of a world passed away, which are hidden beneath three miles of salt-water? The letter which Dr. Wyville Thomson wrote to Dr. Carpenter in May, 1868, out of which all these expeditions have grown, shows that this query had become a practical problem in Dr. Thomson's mind at that time; and the desirableness of solving the problem is put in the foreground of his reasons for urging the government to undertake the work of exploration:

"Two years ago, M. Sars, Swedish Government Inspector of Fisheries, had an opportunity, in his official capacity, of dredging off the Loffoden Islands at a depth of 300 fathoms. I visited Norway shortly after his return, and had an opportunity of studying with his father, Prof. Sars, some of his results. Animal forms were *abundant;* many of them were new to science; and among them was one of surpassing interest, the small crinoid, of which you have a specimen, and which we at once recognized as a degraded type of the

[1] "Memoirs of the Geological Survey of Great Britain," vol. i., p. 390.

[2] "Lay Sermons," etc., "On a Piece of Chalk."

Apiocrinidæ, an order hitherto regarded as extinct, which attained its maximum in the Pear Encrinites of the Jurassic period, and whose latest representative hitherto known was the *Bourguettocrinus* of the chalk. Some years previously, Mr. Absjörnsen, dredging in 200 fathoms in the Hardangerfjord, procured several examples of a star-fish (*Brisinga*), which seems to find its nearest ally in the fossil genus *Protaster*. These observations place it beyond a doubt that animal life is abundant in the ocean at depths varying from 200 to 300 fathoms, that the forms at these great depths differ greatly from those met with in ordinary dredgings, and that, at all events, in some cases, these animals are closely allied to, and would seem to be directly descended from, the Fauna of the early tertiaries.

"I think the latter result might almost have been anticipated; and, probably, further investigation will largely add to this class of data, and will give us an opportunity of testing our determinations of the zoological position of some fossil types by an examination of the soft parts of their recent representatives. The main cause of the destruction, the migration, and the extreme modification of animal types, appears to be change of climate, chiefly depending upon oscillations of the earth's crust. These oscillations do not appear to have ranged, in the northern portion of the Northern Hemisphere, much beyond 1,000 feet since the commencement of the Tertiary epoch. The temperature of deep waters seems to be constant for all latitudes at 39°, so that an immense area of the North Atlantic must have its conditions unaffected by tertiary or post-tertiary oscillations."[1]

As we shall see, the assumption that the temperature of the deep sea is everywhere 39° Fahr. (4° Cent.) is an error, which Dr. Wyville Thomson adopted from eminent physical writers; but the general justice of the reasoning is not affected by this circumstance, and Dr. Thomson's expectation has been, to some extent, already verified. Thus, besides *Globigerina*, there are eighteen species of deep-sea *Foraminifera* identical with species found in the chalk.

Embedded in the chalky mud of the deep sea, in many localities, are innumerable cup-shaped sponges, provided with six-rayed silicious spicula, so disposed that the wall of the cup is formed of a lace-work of flinty thread. Not less abundant, in some parts of the chalk formation, are the fossils known as *Ventriculites*, well described by Dr. Thomson as "elegant vases or cups, with branching, root-like bases, or groups of regularly or irregularly spreading tubes delicately fretted on the surface with an impressed net-work like the finest lace;" and, he adds: "When we compare such recent forms as *Aphrocallistes*, *Iphiteon*, *Holtenia*, and *Askonema*, with certain series of the chalk *Ventriculites*, there cannot be the slightest doubt that they belong to the same family—in some cases to very nearly-allied genera."[2]

Prof. Duncan finds "several corals from the coast of Portugal more nearly allied to chalk-forms than to any others."

The stalked crinoids, or feather-stars, so abundant in ancient times, are now exclusively confined to the deep sea, and the late explorations

[1] "The Depths of the Sea," pp. 51, 52. [2] Ibid., p. 484.

have yielded forms of old affinity, the existence of which has hitherto been unsuspected. The general character of the group of star-fishes embedded in the white chalk is almost the same as in the modern Fauna of the deep Atlantic. The sea-urchins of the deep sea, while none of them are specifically identical with any chalk-form, belong to the same general groups, and some closely approach extinct cretaceous genera.

Taking these facts in conjunction with the positive evidence of the existence, during the Cretaceous epoch, of a deep ocean where now lies the dry land of Central and Southern Europe, Northern Africa, and Western and Southern Asia; and of the gradual diminution of this ocean during the older Tertiary epoch, until it is represented at the present day by such teacupfuls as the Caspian, the Black Sea, and the Mediterranean; the supposition of Dr. Thomson and Dr. Carpenter that what is now the deep Atlantic was the deep Atlantic (though merged in a vast easterly extension) in the Cretaceous epoch, and that the *Globigerina* mud has been accumulating there from that time to this, seems to me to have a great degree of probability. And I agree with Dr. Wyville Thomson against Sir Charles Lyell (it takes two of us to have any chance against his authority) in demurring to the assertion that "to talk of chalk having been uninterruptedly formed in the Atlantic is as inadmissible in a geographical as in a geological sense."

If the word "chalk" is to be used as a stratigraphical term and restricted to *Globigerina* mud deposited during the Cretaceous epoch, of course it is improper to call the precisely similar mud of more recent date chalk. If, on the other hand, it is to be used as a mineralogical term, I do not see how the modern and the ancient chalks are to be separated; and, looking at the matter geographically, I see no reason to doubt that a boring-rod driven from the surface of the mud which forms the floor of the mid-Atlantic would pass through one continuous mass of *Globigerina* mud, first of modern, then of tertiary, and then of mesozoic date; the "chalks" of different depths and ages being distinguished merely by the different forms of other organisms associated with the *Globigerinæ*.

On the other hand, I think it must be admitted that a belief in the continuity of the modern with the ancient chalk has nothing to do with the proposition that we can, in any sense whatever, be said to be still living in the Cretaceous epoch. When the Challenger's trawl brings up an Ichthyosaurus, along with a few living specimens of Belemnites and Turrilites, it may be admitted that she has come upon a cretaceous "outlier;" but a geological period is characterized not only by the presence of those creatures which lived in it, but by the absence of those which have only come into existence later; and, however large a proportion of true cretaceous forms may be discovered in the deep sea, the modern types associated with them must be abolished before the Fauna, as a whole, could, with any propriety, be termed Cretaceous.

I have now indicated some of the chief lines of Biological inquiry, in which the Challenger has special opportunities for doing good service, and in following which she will be carrying out the work already commenced by the Lightning and Porcupine in their cruises of 1868 and subsequent years.

But biology, in the long-run, rests upon physics, and the first condition for arriving at a sound theory of distribution in the deep sea is, the precise ascertainment of the conditions of life; or, in other words, a full knowledge of all those phenomena which are embraced under the head of the "Physical Geography of the Ocean."

Excellent work has already been done in this direction, chiefly under the superintendence of Dr. Carpenter, by the Lightning and the Porcupine,[1] and some data of fundamental importance to the physical geography of the sea have been fixed beyond a doubt.

Thus, though it is true that sea-water steadily contracts as it cools down to its freezing-point, instead of expanding before it reaches its freezing-point as fresh water does, the truth has been steadily ignored by even the highest authorities in physical geography, and the erroneous conclusions deduced from their erroneous premises have been widely accepted as if they were ascertained facts. Of course, if sea-water, like fresh water, were heaviest at a temperature of 39° Fahr., and got lighter as it approached 32°, the water of the bottom of the deep sea could not be colder than 39°. But one of the first results of the careful ascertainment of the temperature at different depths, by means of thermometers specially contrived for the avoidance of the errors produced by pressure, was the proof that, below 1,000 fathoms in the Atlantic, down to the greatest depths yet sounded, the water has a temperature yet lower than 38° Fahr., whatever be the temperature of the water at the surface. And that this low temperature of the deepest water is probably the universal rule for the depths of the open ocean is shown, among others, by Captain Chimmo's recent observations in the Indian Ocean, between Ceylon and Sumatra, where, the surface-water ranging from 85° to 81° Fahr., the temperature at the bottom, at a depth of 2,270 to 2,656 fathoms, was only from 34° to 32° Fahr.

As the mean temperature of the superficial layer of the crust of the earth may be taken at about 50° Fahr., it follows that the bottom layer of the deep sea in temperate and hot latitudes is, on the average, much colder than either of the bodies with which it is in contact; for the temperature of the earth is constant, while that of the air rarely falls so low as that of the bottom water in the latitudes in question; and, even when it does, has time to affect only a compara-

[1] "Proceedings of the Royal Society," 1870 and 1872.

tively thin stratum of the surface-water before the return of warm weather.

How does this apparently anomalous state of things come about? If we suppose the globe to be covered with a universal ocean, it can hardly be doubted that the cold of the regions toward the poles must tend to cause the superficial water of those regions to contract and become specifically heavier. Under these circumstances, it would have no alternative but to descend and spread over the sea-bottom, while its place would be taken by warmer water drawn from the adjacent regions. Thus, deep, cold, polar-equatorial currents, and superficial, warmer, equatorial-polar currents, would be set up; and, as the former would have a less velocity of rotation from west to east than the regions toward which they travel, they would not be due southerly or northerly currents, but southwesterly in the Northern Hemisphere, and northwesterly in the Southern; while, by a parity of reasoning, the equatorial-polar warm currents would be northeasterly in the Northern Hemisphere, and southeasterly in the Southern. Hence, as a northeasterly current has the same direction as a southwesterly wind, the direction of the northern equatorial-polar current in the extratropical part of its course would pretty nearly coincide with that of the anti-trade winds. The freezing of the surface of the polar sea would not interfere with the movement thus set up. For, however bad a conductor of heat ice may be, the unfrozen sea-water immediately in contact with the under surface of the ice must needs be colder than that farther off; and hence will constantly tend to descend through the subjacent warmer water.

In this way it would seem inevitable that the surface-waters of the northern and southern frigid zones must, sooner or later, find their way to the bottom of the rest of the ocean; and there accumulate to a thickness dependent on the rate at which they absorb heat from the crust of the earth below, and from the surface-water above.

If this hypothesis be correct, it follows that, if any part of the ocean in warm latitudes is shut off from the influence of the cold polar underflow, the temperature of its deeps should be less cold than the temperature of corresponding depths in the open sea. Now, in the Mediterranean, Nature offers a remarkable experimental proof of just the kind needed. It is a land-locked sea which runs nearly east and west, between the twenty-ninth and forty-fifth parallels of north latitude. Roughly speaking, the average temperature of the air over it is 75° Fahr. in July, and 48° in January.

This great expanse of water is divided by the peninsula of Italy (including Sicily), continuous with which is a submarine elevation carrying less than 1,200 feet of water, which extends from Sicily to Cape Bon in Africa, into two great pools—an eastern and a western. The eastern pool rapidly deepens to more than 12,000 feet, and sends off to the north its comparatively shallow branches, the Adriatic and the

Ægean Seas. The western pool is less deep, though it reaches some 10,000 feet. And, just as the western end of the eastern pool communicates by a shallow passage, not a sixth of its greatest depth, with the western pool, so the western pool is separated from the Atlantic by a ridge which runs between Capes Trafalgar and Spartel, on which there is hardly 1,000 feet of water. All the water of the Mediterranean which lies deeper than about 150 fathoms, therefore, is shut off from that of the Atlantic, and there is no communication between the cold layer of the Atlantic (below 1,000 fathoms) and the Mediterranean. Under these circumstances, what is the temperature of the Mediterranean? Everywhere below 600 feet it is about 55° Fahr.; and consequently, at its greatest depths, it is some 20° warmer than the corresponding depths of the Atlantic.

It seems extremely difficult to account for this difference in any other way than by adopting the view so strongly and ably advocated by Dr. Carpenter, that, in the existing distribution of land and water, such a circulation of the water of the ocean does actually occur, as theoretically must occur, in the universal ocean, with which we started.

It is quite another question, however, whether this theoretic circulation, true cause as it may be, is competent to give rise to such movements of sea-water, in mass, as those currents, which have commonly been regarded as northerly extensions of the Gulf Stream. I shall not venture to touch upon this complicated problem; but I may take occasion to remark that the cause of a much simpler phenomenon—the stream of Atlantic water which sets through the Straits of Gibraltar, eastward, at the rate of two or three miles an hour or more, does not seem to be so clearly made out as is desirable.

The facts appear to be that the water of the Mediterranean is very slightly denser than that of the Atlantic (1.0278 to 1.0265), and that the deep water of the Mediterranean is slightly denser than that of the surface; while the deep water of the Atlantic is, if any thing, lighter than that of the surface. Moreover, while a rapid superficial current is setting in (always, save in exceptionally violent easterly winds) through the Straits of Gibraltar, from the Atlantic to the Mediterranean, a deep under-current (together with variable side-currents) is setting out through the Straits, from the Mediterranean to the Atlantic.

Dr. Carpenter adopts, without hesitation, the view that the cause of this indraught of Atlantic water is to be sought in the much more rapid evaporation which takes place from the surface of the Mediterranean than from that of the Atlantic; and thus, by lowering the level of the former, gives rise to an indraught from the latter.

But is there any sound foundation for the three assumptions involved here: Firstly, that the evaporation from the Mediterranean, as a whole, is much greater than that from the Atlantic under corresponding parallels; secondly, that the rainfall over the Mediterranean makes up for evaporation less than it does over the Atlantic; and thirdly, supposing these two questions answered affirmatively: Are not these sources of loss in the Mediterranean fully covered by the prodigious quantity of fresh water which is poured into it by great rivers and submarine springs? Consider that the water of the Ebro, the Rhine, the Po, the Danube, the Don, the Dnieper, and the Nile, all flow directly or indirectly into the Mediterranean; that the volume of fresh water which they pour into it is so enormous that fresh water may sometimes be baled up from the surface of the sea off the Delta of the Nile, while the land is not yet in sight; that the water of the Black Sea is half fresh, and that a current of three or four miles an hour constantly streams from it Mediterraneanward through the Bosporus; consider, in addition, that no fewer than ten submarine springs of fresh water are known to burst up in the Mediterranean, some of them so large that Admiral Smyth calls them "subterranean rivers of amazing volume and force;" and it would seem, on the face of the matter, that the sun must have enough to do to keep the level of the Mediterranean down; and that, possibly, we may have to seek for the cause of the small superiority in saline contents of the Mediterranean water in some condition other than solar evaporation.

Again, if the Gibraltar indraught is the effect of evaporation, why does it go on in winter as well as in summer?

All these are questions more easily asked than answered; but they must be answered before we can accept the Gibraltar stream as an example of a current produced by indraught, with any comfort.

The Mediterranean is not included in the Challenger's route, but she will visit one of the most promising and little explored of hydrographical regions—the North Pacific, between Polynesia and the Asiatic and American shores; and, doubtless, the store of observations upon the currents of this region, which she will accumulate, when compared with what we know of the North Atlantic, will throw a powerful light upon the present obscurity of the Gulf Stream problem.—*Contemporary Review.*

CONDENSED MILK IN ENGLAND.

By Dr. EDWARD LANKESTER.

THE importance of milk as an article of diet is so great that any thing offered as a substitute for it, or that renders it more available as food, demands attention. The composition of cow's milk is so nearly like woman's milk that the addition of a little water and sugar may be said to convert the one into the other; hence the practice of giving cow's milk to young children, and making it a substantial article of their diet long after they have cut their teeth and are able to masticate bread and meat. No inconsiderable quantity of milk is also consumed by adults, and its nutritive effect is not exceeded by any article of diet, as it contains all the constituents that are necessary to the perfect nutrition of the human body.

There are, however, several drawbacks in the use of cow's milk which diminish its utility, limit its use, and sometimes render it dangerous. One of the great drawbacks in milk is its liability to decomposition. The sugar it contains becomes acid, the caseine separates in the form of curd, and a fermentation ensues which renders it unpleasant and sometimes even dangerous as an article of diet. The latter effect is seen more particularly in young children. During the summer months they suffer extensively from diarrhœa, and there is little doubt that this is largely due to the acidity of the milk which is given to them. Milk bought in the morning in London is frequently unfit to be used in the evening for the diet of infants. These changes in milk are hastened by the present system of bringing milk to London from a distance in cans, by which means it is shaken, and its tendency to change hastened.

Another drawback in the use of milk is its liability to adulteration. Unfortunately, the agent by which milk is adulterated is easily accessible, and can be detected with great difficulty. We cannot instruct cooks and poor people in the use of lactometers and hydrometers by which the learned test milk; moreover, the natural liability of milk to vary is very great. Thus the quantity of cream in milk received by the Aylesbury Condensed Milk Company varies from 9 to 17 per cent. Dr. Hassell states that the cream given by the milk of a cow, the milk of which he personally inspected, was but 4½ per cent. Although, then, all milk containing less than 9 per cent. of cream may be suspected of adulteration, yet it may happen that a milk containing but 4½ per cent. may be really not adulterated with water at all.

This varying quantity of cream also shows that, even when milk is not adulterated, it is liable to great variations in the quantity of cream which may be taken as the measure of its usefulness as an article of food.

Many attempts have been made to overcome these objections to the use of milk, and from time to time preparations of it have been sold by which freedom from acidity and adulteration is secured. The most available of these preparations have been those that submitted the milk to a process of evaporation by which more or less of the water naturally contained in milk is got rid of. By these processes the nutritive constituents of the milk are retained; the preparation keeps for some time, is easily conveyed from place to place, and, by the addition of water, milk, so to speak, is readily manufactured. None of these preparations, however, seemed to succeed till a process for making what is called "condensed milk" was introduced. Whether

America or Europe has the honor of the invention we need not dispute here. It is now made in this country by thousands of gallons daily, and its manufacture may be witnessed on a large scale at Aylesbury.

Although the process of evaporating milk may be regarded as an exceedingly simple one, the attempt to carry it out at Aylesbury on a large scale has developed a complicated machinery in which steam-power is extensively used; 200 persons are employed, and the milk of 1,200 cows, each yielding 14 quarts, is daily evaporated. The milk used is brought from farms in the neighborhood in ordinary tin cans. Each can before it is sent to the factory is carefully tested by the taste and smell and the lactometer. Any doubtful specimens are set aside for reëxamination or rejection. The milk is then passed into a vacuum pan, and the vapor thus produced is carried off and condensed and thrown away. When the milk has acquired a proper consistence, it is mixed with sugar. This addition of sugar is the distinguishing feature of the condensed-milk process. After this the milk is still further condensed till it reaches the required consistence, and is run off into the little tin cans which are so well known. The whole of these operations are carried out with a regard for cleanliness which would look almost fastidious if it were not known that a single particle of decomposing milk allowed to get into the receiving-pans might destroy the whole mass. Every can is returned thoroughly cleansed to the farmer who sends it, having been first submitted to hot water, then to a jet of steam, and then rinsed out by a jet of cold water.

The condensed milk thus prepared is of a semi-liquid consistence, and can be taken out of a jar with a spoon. Several analyses of this milk have been made. The late Baron Liebig found that it contained—

Water	22.44
Solids	77.56
	100.00

The *Lancet* has more recently published the following analysis:

Moisture	25.10
Butter	11.73
Caseine	15.17
Milk-sugar	16.24
Cane-sugar	29.46
Ash	2.30
	100.00

From these analyses it will at once be seen that the only perceptible difference between condensed milk and ordinary milk is, that the former contains more sugar and less water than the latter. Both these things are necessary for attaining the objects for which condensed milk is manufactured. The diminution of the bulk of the water from 87 per cent. in ordinary milk to 25 per cent. in the condensed secures diminution of the bulk of the milk, and thus renders transportation comparatively easy. The condensed milk is easily converted to the condition of ordinary milk by the addition of either cold or hot water. The addition of the sugar is found to be necessary, in order to enable the other constituents to resist decomposition. Milk will keep any length of time when entirely desiccated, but, by the process of drying entirely, the milk loses its flavor and many of its properties. The semi-liquid condition of condensed milk prevents these changes, but in this state it is liable to decompose; hence the necessity of additional sugar.

The question arises as to whether this added sugar in any way interferes with the quality of the milk in its relation to the diet of infants or invalids. In comparing human milk with cow's milk, we find that the latter contains more caseine and less sugar than the former. Hence, when given to children, it is customary to add a little water and a little sugar to make it like mother's milk. This object is really effected by the addition of cane-sugar to the condensed milk, and it may, therefore, be unhesitatingly employed in the nursery as a substitute for ordinary cow's milk.

After a personal inspection of the Aylesbury manufactory, and a full consideration of the whole subject, we are quite prepared to say that, where good fresh cow's milk is unattainable, as it is almost practically so in our large towns, there is no substitute for it equal to condensed milk. Nor is this a matter of theory; hundreds of gallons are being used every day in London, and most of it under the direction of experienced medical men. One medical man assures us that he has a healthy, fine-grown child of ten months that has never taken any thing but condensed milk. As the diet of invalids, it may in some cases require watching when the action of sugar is injurious to the system; but in these cases milk should be altogether interdicted.

It is to be hoped that no disadvantage in the use of this agent has been overlooked, as the advantages of its use are so many and so obvious. It presents a pure form of milk in a condition in which it may be kept for any length of time, and is not injured by removal. It is always at hand night and day, and, by the addition of cold or hot water, can be converted into nutritious and wholesome food.—*Nature.*

LOWLY VEGETABLE FORMS.

BY REV. HUGH MACMILLAN.

LIFE is everywhere. "Nature *lives*," says Lewes; "every pore is bursting with life; every death is only a new birth; every grave a cradle." "The earth-dust of the universe," says Jean Paul, "is inspired by the breath of the great God. The world is brimming with life; every leaf on every tree is a land of spirits." The tendency to vegetate is a ceaseless power. It has been in operation from the earliest ages of the earth, ever since living beings were capable of existing upon its surface; and so active in the past history of the globe has been this tendency, that most of the superficial rocks of the earth's crust are composed of the remains of plants. It operates with undiminished and tireless energy still. Vegetation takes place upon almost every substance; upon the bark of trees, upon naked rocks, upon the roofs of houses, upon dead and living animal substances, upon glass when not constantly kept clean, and even on iron which had been subjected to a red heat a short time before. Zoologists tell us, when speaking of animalcules, that not a drop of stagnant water, not a speck of vegetable or animal tissue, not a portion of organic matter, but has its own appropriate inhabitants. The same may be said of plants; for we can hardly point to a single portion of the earth's surface which is not tenanted by some vegetable form whose structure is wonderfully adapted to its situation and requirements. Even in the hottest thermal springs, and on the eternal snows of the arctic regions, peculiar forms of vegetation have been found. From the deepest recesses of the earth to which the air can penetrate, to the summits of the loftiest mountains; from the almost unfathomable depths of the ocean to the highest clouds; from pole to pole, the vast stratum of vegetable life extends; while it ranges from a temperature of 35° to 135° Fahr., a range embracing almost every variety of conditions and circumstances.

The most cursory and superficial glance will recognize in every scene a class of plants whose singular appearances, habits, and modes of growth, so prominently distinguish them from the trees and flowers around, that they might seem hardly entitled to a place in the vegetable kingdom at all. On walls by the wayside, on rocks on the hills, and on trees in the woods, we see tiny green tufts and gray stains, or party-colored rosettes spreading themselves, easily dried by the heat of the sun, and easily revived by the rain. In almost every stream, lake, ditch, or any collection of standing or moving water, we observe a green, slimy matter, forming a scum on the surface, or floating in long filaments in the depths. On almost every fallen leaf and decayed branch, fleshy, gelatinous bodies of different forms and sizes meet our eye. Sometimes all these different objects appear growing on the same substance. If we examine a fallen, partially-decayed twig, half-buried in the earth in a wood, we may find it completely covered with various representatives of these different vegetable growths; and nothing surely can give us a more striking or convincing proof of the universal diffusion of life. All these different plants belong to the second great division of the vegetable kingdom, to which the name of *Cryptogamia* has been given, on account of the absence, in all the members, of those prominent organs which are essential to the production of perfect seed. They are propagated by little embryo plants called spores, or sporules, generally invisible to the naked eye, and differing from true seeds in germinating from any part of their surface instead of from two invariable points. Besides this grand distinguishing mark, they possess several other peculiar qualities in common. They consist of cells only, and hence are often called cellular plants, in contradistinction to those plants which are possessed of fibres and woody tissue. Their development is also superficial, growth taking place from the various terminal points; and hence they are called acrogens and thallogens, to distinguish them from monocotyledonous and dicotyledonous plants. Popularly, they are known as mosses, lichens, algæ, and fungi. They open up a vast field of physiological research. They constitute a microcosm, a strange minute world underlying this great world of sense and sight, which, though unseen and unheeded by man, is yet ever in full and active operation around us. It is pleasant to turn aside for a while from the busy human world, with its ceaseless anxieties, sorrows, and labors, to avert our gaze from the splendors of forest and garden, from the visible display of green foliage and rainbow-colored blossoms around us, and contemplate the silent and wonderful economy of that other world of minute or invisible vegetation with which we are so mysteriously related, though we know it not. There is something exceedingly interesting in tracing Nature to her ultimate and simplest forms. The mind of man has a natural craving for the infinite. It delights to speculate either on the vast or the minute; and we are not surprised at the paradoxical remark of Linnæus, that Nature appeared to him greatest in her least productions.

These plants once occupied the foremost position in the economy of Nature. Like many decayed families whose founders were kings and mighty heroes, but whose descendants are beggars, they were once the aristocracy of the vegetable kingdom, though now reduced to the lowest ranks, and considered the *canaille* of vegetation. Geology reveals to us the extraordinary fact that one whole volume of the earth's stony book is filled almost exclusively with their history. Life may have been ushered upon our globe through oceans of the lowest types of *Confervæ*, long previous to the deposit of the oldest palæozoic rocks as known to us; and for myriads of ages these extremely simple and minute plants may have represented the only idea of life on earth. But, passing from conjecture to the domain of established truth, we know of a certainty that, at least throughout the vast periods of the Carboniferous era, ferns, mosses, and still humbler plants, occupied the throne of the vegetable kingdom, and, by their countless numbers, their huge dimensions, and rank luxuriance, covered the whole earth with a closely-woven mantle of dark-green verdure—from Melville Island in the extreme north, to the islands of the Antarctic Ocean in the extreme south. The relics of these immense primeval forests, reduced to a carbonaceous or bituminous condition by the secret resources of Nature's laboratory, amid so many convulsions of the globe, are now buried deep in the bowels of the earth, packed into solid sandstone cases, and under huge shady covers, and stored up in the smallest compass by the mighty pressure of ponderous rock-presses, constituting the chief source of our domestic comfort, and of nearly all our commercial greatness. A coal-bed is, in fact, a *hortus siccus* of extinct cryptogamic vegetation, bringing before the imagination a vista of the ancient world, with which no arrangement of landscape or combination of scenery can now be compared; and, gazing upon its dusky contents, our minds are baffled in aiming to comprehend the bulk of original material, the seasons of successive growth, and the immeasurable years or ages which passed while decay, and maceration, and chemical changes, prepared the fallen vegetation for fuel. If the specimens of plants, thus strangely preserved, teach us one truth more than another, it is this, that size and development are terms of no meaning when applied to a low or a high type of organization. The *Cryptogamia* of the Old World, the earliest planting in the new-formed soil, are in bulk, as well as in elegance and beauty of form, unrivalled by the finest specimens of the modern forest. The little and the great, the recent and the extinct, were equally the objects of Nature's care, and were all modelled with a skill and finish that left nothing to be added.

And as in early geological epochs they occupied so conspicuous a position, so now in the annals of physical geography they are entitled to a prominent place. With the exception of the grasses—Nature's special favorites—they are the most abundant of all plants, possessing inconceivable myriads of individual representatives in every part of the globe, from which unfavorable conditions exclude all other vegetation; and thus they contribute, far more than we are apt from a superficial observation to imagine, to the picturesque and romantic appearances exhibited by scenery, and to the formation of that richly-woven and beautifully-decorated robe of vegetation which conceals the ghastly skeleton of the earth, and hides from our view the rugged outlines and primitive features of Nature. They are the first objects that clothe the naked rocks which rise above the surface of the ocean; and they are the last traces of vegetation which disappear under degrees of heat and cold fatal to all life. Their structure is so singularly varied and plastic, that they are adapted to every possible situation. In every country they form an important element in the number of plants, the proportion to flowering plants decreasing from and increasing toward the poles. Taking them as a whole, and in regard to their size, they occupy a larger area of the earth's surface than any other kind of vegetation. There are immense forests of trees here and there in different countries, realizing Cowper's wish for "a boundless contiguity of shade;" there are vast colonies of flowering plants; but the range of the most ubiquitous tree or flower is vastly inferior to that of some of the humblest lichens and mosses. Although these plants occupy but a very subsidiary and unimportant position among the vegetation which surrounds us in our daily walks, and are concealed in isolated patches in the woods and fields by the luxuriance of higher and more conspicuous plants, yet they constitute the sole vegetation of very extensive regions of the earth's surface. Every part of the globe, within a thousand feet of the line of perpetual snow, is redeemed from utter desolation by these plants alone. Above the valleys and the lower slopes which form the step of transition from plain to mountain—inhabited by prosperous and civilized nations—is the domain of mist and mystery, the region of storm—a world which is not of this world, where God and Nature are all in all, and man is nothing; and in this unknown region there are immense tracts familiar to the eye of wild bird, to the summer cloud, the stars and meteors of the night—strange to human faces and the sound of human voices, where the lichen and the moss alone luxuriate and carpet the sterile ground. The grandest and sublimest regions of the earth are adorned with garlands of the minutest and humblest plants; they are the tapestry, the highly-wrought carpeting laid down in the vestibules of Nature's palaces. If we look at a map of the world, we see that Europe and Asia are held together as it were by a huge ridge or backbone of mountain-elevation, which, although suffering partial interruption, may be roughly described as continuous from one ocean to another. It begins with the mountains of Biscay in Spain, passes on through the Pyrenees, with a slight interruption, into the Alps, which throw off the important spur or rib of the Apennines; thence it divides into the Balkan and Carpathians. We trace the chain next in the Caucasus and the mountains of Armenia—with the interruption of the Caspian Sea—passing into the Hindoo Coosh and the Himalaya Mountains, whence the chain forks and takes a direction north and south, enclosing like walls the whole delta of China, and thence dips into the eastern ocean. In Africa also, at its widest part, there is a similar backbone, beginning not far from Sierra Leone, and losing itself in the east in the mountains of Abyssinia; while in America the mountain-spine trends north and south from the Hudson's Bay territories, through the Rocky Mountains, uninterruptedly through the Isthmus of Panama, along the Andes to the Straits of Magellan. These vast mountain-systems, with their culminating regions in the Andes, Alps, and Himalayas, and their subsidiary branches or ribs in the Grampians, Dovrefields, Ural, and Atlantic ranges, are clothed on their sides, summits, and elevated plateaus, almost exclusively with cryptogamic vegetation, and enable us to form some conception of the immense altitudinal range of these plants. Then there are whole islands in the Arctic and Antarctic Oceans whose vegetation also is almost entirely cellular. The northern portion of Lapland, the continent of Greenland, the large islands of Spitzbergen, Nova Zembla, and Iceland, the extensive territories of the Hudson's Bay Company, the enormous tracts of level land which border the Polar Ocean from the North Cape to Behring's Straits, across the north of Europe and Asia, and from Behring's Straits to Greenland, across the north of America, a stretch of many thousands of miles; all these immense areas of the earth's surface—where not a tree, nor a shrub, nor a flower is seen, except the creeping arctic willow and birch, and the stunted moss-like saxifrage and scurvy-grass—are covered with fields of lichens and mosses, far exceeding any thing that can be compared in that respect among phanerogamous plants. Thus, to the rugged magnificence of Alpine scenery, and the dreary isolation and uniformity of the arctic steppes, and the boundless wastes of brown desert and misty moorland, to these great outlets from civilization and the tameness of ordinary life, which allow the soul to expand and go out in sublime imaginings toward the infinity of God, these humble plants form the sole embellishments.

So much for the distribution of these plants on the land; their range in the waters is still more extensive. Lichens and mosses cover the waste surfaces of the earth; diatoms and confervæ are everywhere miraculously abundant in the waters—in rivers and streams, in ditches and ponds, alike under the sunny skies of the south, and in the frozen regions of the north; on the surface of the sea in floating meadows, and in the dark and dismal recesses of the ocean only to be explored by the long line of the sounding-lead. The ocean swarms with innumerable varieties, without their presence being indicated by any discoloration of the fluid. The Arctic and Antarctic Oceans, covering areas larger than the Continents of Europe and Asia, are peopled by myriads of diatoms; various inland seas and lakes are tinged of different hues by their predominance in the waters; while it has been ascertained, from the soundings obtained during the investigations connected with laying the electric telegraph-cable between Ireland and Newfoundland, that the floor of the Atlantic is paved many feet deep with their silicious shields, preserving in all their integrity their wonderful shapes, notwithstanding their extreme delicacy and minuteness, and the enormous pressure of the vast body of water which rests above them. Such is the wide space which these organisms occupy in the fields of Nature—a prominence which is surely sufficient to redeem them from the charge of insignificance. They are inferior in majesty of form to palms and oaks, but in their united influence it is not too extravagant to say that they are not less important than the great forests of the world.

This vast profusion of minute and humble vegetable life serves the obvious purpose of preparing the way for higher orders of vegetation. Nature is incessantly working out vast ends by humble and scarcely recognizable means. The features of the earth are being continually altered by the germination and dispersion of the algæ, mosses, and lichens. Bare and sterile mountains are clothed with verdure; rocks are mouldering into soil; seas are filling up; rivers and streams are continually shifting their outlines; and lakes are converted into fertile meadows and the sites of luxuriant forests, by means of the vast armies of Nature's pioneers. Hard inorganic matters are reduced to impalpable atoms; waters and gases are decomposed and moulded into new forms and substances having new properties, by vegetable growth. Minute as these plants are, they are intimately related to the giant forms of the universe. It has been observed that as the great whole is indissolubly connected with its minutest parts, so the germination of the minutest lichen and the growth of the simplest moss are directly linked with the grandest astronomical phenomena; nor could the smallest fungus or conferva be annihilated without destroying the equilibrium of the universe. It is with organic Nature as with the body politic or the microcosm of the human frame, if "one member suffer all the members suffer with it," and the loss of one class or order would involve that of another, till all would perish. Our comfort and health, nay our very existence, more or less immediately depend on the useful functions which they perform. Before we can have the wheat which forms our daily bread, or the grass which yields us, through the instrumentality of our herds, our daily supply of animal food, or the cotton and lint which form our clothes, countless generations of lichens and mosses must have been at work preparing a soil for the growth of the plants which produce these useful materials. And as on the dry land, so in the great waters, this wonderful chain of connection exists in all its complexity. Before the reader can peruse these pages by the light of the midnight lamp, or the gay party can indulge their revels under the brilliant glare of spermaceti tapers, myriads of minute diatoms and *Confervæ*, floating in the waters of the sea, must have formed a basis of subsistence for the whales and seals whose oil is employed for these purposes. Man's own structure is nourished and built up by the particles which these active plants have rescued from the mineral kingdom, and which once circulated through their simple cells; and thus the highest and most complex creature, by a vital sympathy and a close physical relation, is connected with the lowest and simplest organism, to teach him humility, and inspire him with a deep interest in all the works of his Maker!

"Nothing in this world is single;
All things, by a law divine,
In one another's being mingle."

It may be asked by a class of individuals, unfortunately too numerous, What is the use of these minute plants? In the business language of the world things are called useful when they promote the profit, convenience, or comfort, of every-day life; and useless when they do not promote, or when they hinder, either of these desired ends. But this definition is extremely partial and one-sided. There are higher purposes to serve in this world than mere subservience to the physical wants of man. There is a much higher utility than the mere temporary and worldly one. The useful things of external life, indeed, should not be undervalued; they are the first things required, but they are not the sole or the highest things necessary. Man must have food and clothing in order to live; but it must also be remembered that man does not live by bread and the conveniences of external life alone. When any one does live by these alone, he has forfeited his claim to the higher form of life which is his glorious privilege, and by which he is distinguished from the lower animals. Nature throughout her whole wide domains gives no countenance to such a materialistic exclusiveness. She is at once utilitarian and transcendental. Uses and beauties intermingle. All that is useful is around us; but how much more is there besides? There is a strange superfluous glory in the summer air; there is marvellous beauty in the forms and hues of flowers; there is an enchanting sweetness in the song of birds and the murmur of waters; there are a divine grandeur and loveliness in the landscapes of earth and the scenery of the heavens, the changes of the seasons, the dissolving splendors of morning, noon, sunset, and night, utterly incomprehensible upon the theory of Nature's exclusive utilitarianism. "The tree which shades the wayfarer in the noontide heat adorns the landscape; and the flower which gives honey to the bee sheds its perfume on the air. A leaf no less than a flower fulfils the functions of life, ministers to the necessities of man, yet clothes itself, and adorns the earth in tapestries richer than the robes of kings." All things proclaim that the Divine Architect, while amply providing for the physical wants of his creatures, has not forgotten their spiritual necessities and enjoyments; and, having implanted in the human soul a yearning for the beautiful, has surrounded us with a thousand objects by whose charms that yearning may be gratified. And one of the most striking examples of this Divine care is to be seen in the profusion of minute objects spread around us, which apparently have no direct influence at all upon man's physical nature, and have no connection with his corporeal necessities. These objects, subserving no gross utilitarian purpose, are intended to educate man's spiritual faculties by the beauties of form, the wonders of structure, and the adaptations of economy which they display. Their beauty is sufficient reason for their existence, were there no other. When their varied and exquisitely symmetrical forms are presented to the eye under the microscope, a thrill of pleasure is experienced, calm and pure, because free from all taint of passion, and felt all the more intensely because nameless and indefinite. We are brought face to face with perfection in its most wonderful aspect—the perfection of minuteness and detail; with objects which bear most deeply impressed upon them the signet-mark of their Maker; and we observe with speechless admiration that the Divine attention is acuminated and his skill concentrated on these vital atoms; the last visible organism vanishing from our view with the same Divine glory upon it, as the last star that glimmers out of sight on the remotest verge of space.

These organisms further justify their existence to the utilitarian, inasmuch as their study is well calculated to exercise an educational influence which should not be overlooked or despised. While they try the patience, they exercise the faculties by forcing attention upon details. Their minuteness, their general resemblance to each other, their want in many cases of very prominent or marked characteristics, render it a somewhat difficult task to identify them. Long hours may often be spent in ascertaining the name of a single species, and assigning it its proper place in the tribe to which it belongs. One species may often be confounded with another closely allied, and days and weeks may elapse before the eye and the mind, familiarized with their respective details, can observe the distinctions between them. This difficulty of identification greatly sharpens one's knowledge, induces a habit of paying attention to minutiæ, and creates a power of distinguishing between things that differ slightly, which is exceedingly valuable and important. For the eye and mind thus educated to detect resemblances and differences in objects, which to ordinary observation appear widely dissimilar or precisely the same, there will be abundant scope in the practical details of common every-day life, as well as in the higher walks of literature, science, and art.

The study of these plants has also a tendency to elevate and enlarge our conceptions of Nature; its vastness and complexity, its incommunicable grandeur, its all but infinity, opening before us newer and more striking vistas with every descending step we take. The farther we advance, and the wider our sphere of observation extends, wonder follows on wonder, till our faculties become bewildered, and our intellect falls back on itself in utter hopelessness of arriving at the end. Minute as the objects are in themselves, contact with them cannot fail to excite the mind, to call it forth into full and vigorous exercise, to enlist its sympathies, and to expand its faculties. Many eloquent pages have been written to show this elevating influence upon the mind, of contact with and contemplation of the phenomena of Nature; but it is not the great and sublime objects of Nature alone that produce this effect—the sublimity of mountains, the majesty of rivers, and the repose of forests—the very humblest and simplest objects are calculated to awaken these emotions in a yet higher and purer form. "The microscope," as Mr. Lewes has well observed, "is not the mere extension of a faculty; it is a new sense."

There are also peculiar pleasures connected with the study of these objects. There is, first, the pleasure of novelty and discovery—of exploring a realm where every thing is comparatively new, and every step is delightful; where the forms are unfamiliar, and the modes of life hitherto unimagined. There is, next, the more subtle and refined pleasure of observing the strange truths which they unfold, the beautiful laws which they reveal, and the resemblances and relations which they display. The false romanticism of vulgar fancy requires something pretentious and unnatural to gratify its taste; but, to the true poetical mind, the humblest moss on the wall, or the green slime that creams on the wayside pool, will suggest trains of pleasing and profitable reflection. He who has an observing eye and an appreciating mind for these minute wonders of Nature, need never be alone. Every nook and corner of the earth, however barren and dreary to superficial minds, has companions for him; and on every path he will find what the Indians call a *rustawallah*, a delightful road-fellow.

To the cryptogamic botanist Nature reveals herself in her wildest, and also in her fairest aspects. He enters into her guarded retreats—retiring spots of luxuriant, refreshing, and enticing beauty, that are hidden from every other eye; where the great world of strife and toil speaks not, and its cares and sorrows are forgotten, and Nature wakes up the dead divinity within, and rouses the soul to purer and nobler purposes. The peculiar haunts of the objects of his search are found on the sides and summits of lofty mountains, amid the dark, lonely recesses of forests; in the bright bosom of rivers, and lakes, and water-falls; on far-off, unvisited moors, where heaven's serene and passionless blue is the only thing of beauty; and in the mossy retreats of dell and dingle, where Titania and her fays might sport away the dreamy noontide hours. There he finds the pictures which the soul treasures most lovingly; and in these by-ways does he gain the truest insight into the mysteries of life. In thus penetrating into the very heart of Nature, with much toil and exertion it may be, he seems to win her confidence, and to earn the right to look into her arcana. By minute contact and continued commune with her alone in the wilderness, he feels in all its fulness and depth the beautiful relationship that exists between the outer and the inner life of creation. To others the landscape may be the mere background of a picture, in the foreground of which human figures are acting; to him its charms are agencies and influences acting on his heart and mingling with his life. The sportsman in search of game frequently wanders into regions that seem primeval in their solitude, and where "human foot had ne'er or rarely been;" but so absorbing is the pursuit in which he is engaged, that he seldom pauses to watch the features of the surrounding scenery, or to notice combinations of objects and effects of light and shade which Nature never displays, except in such unfrequented spots. But to the cryptogamist, on the other hand, these very scenes of Nature lend a nameless charm and interest to the lowly plants he gathers, and are ever after indelibly associated with them in his memory, and are renewed every time he witnesses their faded remains. Hardly a moment passes over the solitary collector amid such secluded scenes, without some grand effect being produced in the surrounding landscape, or in the appearance of the sky above him; some wonderful transformation of Nature, as though the spot where he stands were her tiring-room, and she were trying on robe after robe to see which became her best; some striking incident, which might well inspire him with the wish to catch the happy moment, and give it a permanent existence. Such are the simple, refining, and enduring pleasures which the cryptogamic botanist enjoys in the pursuit of his favorite study amid the scenes of Nature.

Add to all these recommendations this last important advantage, that these plants can be observed and collected without interruption throughout the whole year, and in situations where other vegetation is reduced to zero. They can be studied alike under the cloudy skies of December, as when illumined by the sunshine of June. When the flowers and ferns have vanished, when the lights are fled, and the garlands are dead, the deserted banquet-hall of Flora is still relieved by the presence of these humble retainers, whose fidelity is proof against every change of circumstance, and whose better qualities are displayed when the storm is wildest and the desolation most complete. They are no summer friends. As Ruskin has beautifully observed: "Unfading as motionless, the worm frets them not, and the autumn wastes not. Strong in lowliness, they neither blanch in heat, nor pine in frost. To them, slow-fingered, constant-hearted, is intrusted the weaving of the dark eternal tapestries of the hills; to them, slow-pencilled, iris-dyed, the tender framing of their endless imagery. Sharing the stillness of the unimpassioned rock, they share also its endurance; and while the winds of departing spring scatter the white hawthorn-blossoms like drifted snow, and summer duns in the parched meadow the drooping of its cowslip gold, far above among the mountains, the silver lichen-spots rest, starlike on the stone, and the gathering orange-stain upon the edge of yonder western peak reflects the sunsets of a thousand years."—*Foot-Notes from the Page of Nature.*

THE WEATHER AND THE SUN.

BY RICHARD A. PROCTOR, B. A.

THERE are few scientific questions of greater interest than the inquiry whether it is possible to find a means of predicting the weather for a long time in advance. In former ages many attempts were made to solve this problem by a reference to the motions of the heavenly bodies. Other methods of prediction were, indeed, in vogue; but I am not here considering ordinary weather portents, or mere scientific schemes for anticipating the weather of two or three coming days: and, with a few trifling exceptions, depending on observations of plants and animals, it is the case that the only wide rules for predicting weather were based on the motions of the sun and moon, the planets and the stars. It must be remembered that even astronomers of repute placed faith, until quite recent years, in the seemingly absurd tenets of judicial astrology. We cannot greatly wonder, therefore, if the more reasonable thesis, that the heavenly bodies determine weather-changes, was regarded with favor. Accordingly we find Horrox, more than two centuries ago, drawing the distinction here indicated, where he says that, in anticipating "storm and tempest" from a conjunction of Mercury with the Sun, he coincides "with the opinion of the astrologers, but in other respects despises their more puerile vanities." We find Bacon in like manner remarking that "all the planets have their summer and winter, wherein they dart their rays stronger or weaker, according to their perpendicular or oblique direction." He says, however, that "the commixtures of the rays of the fixed stars with one another are of use in contemplating the fabric of the world and the nature of the subjacent regions, but in no respect for predictions." Bacon remarks again that reasonable astrology (*Astrologia sana*) "should take into account the apogees and perigees of the planets, with a proper inquiry into what the vigor of planets may perform of itself; for a planet is more brisk in its apogee, but more communicative in its perigee: it should include, also, all the other accidents of the planet's motions, their accelerations, retardations, courses, stations, retrogradations, distances from the sun, increase and diminution of light, eclipses, etc.; for all these things affect the rays of the planets, and cause them to act either weaker or stronger, or in a different manner."

It is a remarkable circumstance that systems of weather prediction based on such considerations were not quickly exploded, owing to their failure when tested by experience. Yet singularly enough it has scarcely ever happened that any wide system of interpretation has been devised, which has not been regarded with favor by its inventor long after it had been in reality disproved by repeated instances of failure. This remark applies to recent systems as well as to those invented in earlier times. Within the last twenty years, for example, methods of prediction based on the moon's movements, on the conjunctions of the planets, and on other relations, have been maintained with astonishing perseverance and constancy, in the face of what outsiders cannot but regard as a most discouraging want of agreement between the predicted weather and the actual progress of events. Here, as in so many cases of prediction, we find the justice of Bacon's aphorism, "Men mark when they hit, and never mark when they miss."

It is noteworthy, indeed, that the very circumstance which appears to present a fatal objection to all schemes of prediction based on the motions of the celestial bodies, supplies the means of imagining that predictions have been fulfilled. The objection I refer to is this: we know that the weather is seldom alike over very wide regions, while, nevertheless, the celestial bodies present the same aspect toward the whole extent of such regions, or an aspect so nearly the same as to suggest that the same conditions of weather should prevail if the weather really depended on the position of the heavenly bodies. It appears, then, that the inventor of a really trustworthy system must have a distinct scheme for each part of every continent—nay, of every country, if not of every county. This objection is not taken into account, however, by the inventors of systems, while the fact on which it depends affords the means of showing that each prediction has been fulfilled. Thus, suppose "bad weather and much wind" have been predicted on a certain day, and that day is particularly fine and calm in London. If this were urged as an objection to the soundness of the system, the answer would run somewhat on this wise: "Unquestionably it was fine in London, but in North Scotland (or in France, or Spain, or Italy, as the case may be) there was very gloomy weather, and in Ireland (suppose) quite strong winds are reported to have prevailed in the afternoon." The readiness with which men satisfy themselves in such cases, corresponds with that mischievous ingenuity wherewith foolish persons satisfy themselves that a fortune-teller had foretold the truth, that a dream had been fulfilled, a superstition justified, and so forth.

The tendency, at present, among those who are desirous of forming a scheme of weather prediction, is to seek the origin of our weather-changes in changes of the sun's condition, and, by determining the laws of the solar changes, to ascertain the laws which regulate changes in the weather.

It may be remarked, in passing, that this new phase of the inquiry does not reject planetary influences altogether. The theory is entertained by many well-known students of science that changes in the condition of the sun are dependent on the varying positions of the planets; so that, if it should be established that our weather-changes are connected with solar changes, we should infer that indirectly the planets in their motions rule the weather on our earth.

I propose now to consider the evidence relating to the sun's influence, and to discuss the question (altogether distinct, be it remarked) whether a means of accurate weather prediction may be obtained *if* the sun's influence be regarded as demonstrated.

There is one strong point in favor of the new theory, in the fact that the sun is unquestionably the prime cause of all weather changes. To quote the words of Lieutenant-Colonel Strange, an enthusiastic advocate of the theory (and eager to have it tested at this country's charge), "there can hardly be a doubt that almost every natural phenomenon connected with the climate can be distinctly traced to the sun as the great dominating force, and it is a natural inference" (though not, as he says, an unavoidable one) "that the changes, and what we now call the uncertainties of climate, are connected with the constant fluctuations which we know to be perpetually occurring in the sun itself." I may proceed, indeed, in this place, to quote the following words, in which Colonel Strange enunciates the theory itself which I am about to discuss, and its consequences: "The bearing of climatic changes on a vast array of problems connected with navigation, agriculture, and health, need but be mentioned to show the importance of seeking in the sun, where they doubtless reside, for the causes which govern these changes. It is indeed my conviction that, of all the fields now open for scientific cultivation, there is not one which, quite apart from its transcendent philosophical interest, promises results of such high utilitarian value as the exhaustive systematic study of the sun."

It cannot be doubted, I think, that, if any thing like what is here promised could be hoped for from the study of the sun, it would be a matter of more than national importance to undertake the task indicated by Colonel Strange. The expense of new observatories for this special subject of study would, in that case, be very fully repaid. It would be worth while to employ the most skilful astronomers at salaries comparable with those which are paid to our Government ministers; it would be well to secure, on corresponding terms, the advice of those most competent to decide on the instrumental requirements of the case; and, in fact, the value of the work which is at present accomplished at Greenwich, great though that value is, would sink into utter insignificance, in my judgment, compared with the results flowing in the supposed case from the proposed "exhaustive and systematic study" of the great central luminary of the planetary system.

The subject we are to discuss is manifestly, therefore, of the utmost importance, and cannot be too carefully dealt with. It would be a misfortune on the one hand to be led by careless reasoning to underestimate the chances in favor of the proposed scheme, while, on the other, it would be most mischievous to entertain unfounded expectations where the necessary experiments must be of a costly nature, and where science would be grievously discredited, should it be proved that the whole scheme was illusory.

We note, first, that, besides being "the great dominating force" to which all natural phenomena connected with climate are due, the sun has special influence on all the most noteworthy *variations* of weather. The seasons are due to solar influence; and here we have an instance of a power of prediction derived from solar study, though belonging to a date so remote that we are apt to forget the fact. It seems so obvious that summer will be on the whole warmer than winter, that we overlook the circumstance that, at some epoch or other, this fact, at least in its relation to the apparent motions of the sun, must have been recognized as a discovery. Men must at one time have learned, or perhaps we should rather say each race of men must at one time have noticed, that the varying warmth on which the processes of vegetation depend, corresponds with the varying diurnal course of the sun. So soon as this was noticed, and so soon as the periodic nature of the sun's varying motions had been ascertained, men had acquired in effect the power of predicting that, at particular times or seasons, the weather on the whole would be warmer than at other seasons. In other words, so soon as men had recognized the period we call the *year*, they could predict that one half of each year would be warmer than the other half. Simple as this fact may seem, it is important to notice it as the beginning of weather-prediction; for, as will presently appear, it has an important bearing on the more complex questions at present involved in the prognostication of weather-changes.

It became manifest, almost as soon as this discovery had been made, that the weather of particular days, or even of weeks and longer periods, could not, by its means, be predicted. A week in summer may be cold, and a week in winter may be warm; nor, so far as is even yet known, is there a single part of any year the temperature of which can be certainly depended upon, at least within the temperate zone. In certain tropical regions there are tolerably constant weather variations; but, so far is this from being the case in the temperate zones of either hemisphere, that it is impossible to affirm certainly, even that during a week or fortnight at any given summer season there will be one hot day, or that during a corresponding period in winter there will be one day of cold weather.

It became manifest also, at an early epoch, that terrestrial conditions must be intimately involved in all questions of weather, since the year in different countries in the same latitudes presents different features. Such differences are of two kinds—those which have a tendency to be constant, and those which are in their nature variable. For example, the annual weather, in Canadian regions having the same range of latitude as Great Britain, differs always to a very marked degree, though not always to the same degree, from that which prevails in this country; here, then, we have a case of a constant difference due unquestionably to terrestrial relations. Again, when we have a hot or dry summer in this country, warm or damp weather may prevail in other countries in the same latitudes, and *vice versa;* differences of this kind are ordinarily[1] variable, and in the present position of weather-science are regarded as accidental.

[1] I use this qualifying word, because some differences of the kind are more or less regular. Thus, when there is a dry summer in certain regions in the west of Europe, there is commonly a wet summer in easterly regions in the same latitude, and *vice versa*, the difference simply depending on the height at which the clouds travel which are brought by the southwesterly counter-trade winds. When these clouds travel high, they do not give up their moisture until they have travelled far inland or toward the east; when they travel low, their moisture is condensed so soon as they reach the western land-slopes. It is not uncommonly the case again that, when we in England have dry summers, much rain falls on the Atlantic, and our drought is simply due to the fall of

Hitherto, weather-science has depended solely on the study of these terrestrial effects as they vary under varying conditions. Modern meteorological research is confined to the record and study of the actual condition of the weather from day to day at selected stations in different countries. It cannot be denied that the inquiry has not been attended with success. At vast expense, millions of records of heat, rainfall, winds, clouds, barometric pressure, and so on, have been secured; but hitherto no law has been recognized in the variations thus recorded—no law, at least, from which any constant system of prediction for long periods in advance can be deduced.

On this point I shall quote, first, a remarkable saying of Sir W. Herschel's, which appears to me, like many such sayings of his, to be only too applicable to the present state of science. In endeavoring to interpret the laws of weather, "we are in the position," Herschel remarks, "of a man who hears at intervals a few fragments of a long history related in a prosy, unmethodical manner. A host of circumstances omitted or forgotten, and the want of connection between the parts, prevent the hearer from obtaining possession of the entire history. Were he allowed to interrupt the narrator, and ask him to explain the apparent contradictions, or to clear up doubts at obscure points, he might hope to arrive at a general view. The questions that we would address to Nature are the very experiments of which we are deprived in the science of meteorology."

The late Prof. De Morgan, indeed, selected meteorology as the subject on which, above all others, systematic observations had been most completely wasted—as a special instance of the failure of the true Baconian method (which, be it noticed, is not, as is so commonly supposed, the modern scientific method). "There is an attempt at induction going on," says De Morgan, "which has yielded little or no fruit, the observations made in the meteorological observatories. This attempt is carried on in a manner which would have caused Bacon to dance for joy" (query); "for he lived in times when chancellors did dance. Russia, says M. Biot, is covered by an army of meteorographs, with generals, high officers, subalterns, and privates, with fixed and defined duties of observation. Other countries, also, have their systematic observations. And what has come of it? Nothing, says M. Biot, and nothing will ever come of it: the veteran mathematician and experimental philosopher declares, as does Mr. Ellis" (Bacon's biographer), "that no single branch of science has ever been fruitfully explored in this way." A special interest attaches, I may remark, to the opinion of M. Biot, because it was given upon the proposal of the French Government to construct meteorological observatories in Algeria.

It is well known that our Astronomer Royal holds a similar opin-

this rain before the clouds from the southwest have reached us. More commonly, however, drought in England is due to the delay of the downfall, in consequence of the clouds from the southwest travelling at a greater height than usual.

ion. De Morgan thus quaintly indicates his interpretation of one particular expression of Sir G. Airy's opinion: "In the report to the Greenwich Board of Visitors, for 1867, the Astronomer Royal, speaking of the increase of meteorological observatories, remarks: 'Whether the effect of this movement will be that millions of useless observations will be added to the millions that already exist, or whether something may be expected to result which will lead to a meteorological theory, I cannot hazard a conjecture.' This *is* a conjecture, and a very obvious one; if Mr. Airy would have given $2\frac{3}{4}d.$ for the chance of a meteorological theory formed by masses of observations, he would never have said what I have quoted."

The simple combination of terrestrial considerations with the effects due to the sun's varying daily path having thus far failed to afford any interpretation of the varying weather from year to year, it is natural to inquire whether the variations in the sun's condition from year to year may not supply the required means of interpreting, and hence of predicting, weather-changes. We know that the sun's condition does vary, because we sometimes see many large spots upon his surface, whereas at others he has no spots, or few and small ones. We can scarcely doubt that these variations affect the supply of heat and light, as well as of chemical action and possibly of other forms of force; and hence we are certainly dealing with a *vera causa*, though whether this real cause be an efficient cause of weather-changes remains yet to be determined.

It may perhaps be as well to inquire, however, in the first place, whether any peculiarities of weather can be traced to another circumstance which ought to be at least as efficient, one would suppose, as any changes in the sun's action due to the spots. I refer to his varying distance from the earth. It is known doubtless to all my readers that, in June and July, although these are our summer months, the sun is farther away than in December; and this, not by an inconsiderable distance, but by more than 3,000,000 miles. Accordingly, on a summer day in our hemisphere, we receive much less heat than is received on a summer day in the Southern Hemisphere. Or, instead of comparing our summer heat with summer heat in the Southern Hemisphere, we may make comparison between the quantity of heat received by the whole earth on a day in June and on a day in December. Either way of viewing the matter is instructive; and I believe many of my readers will be surprised when they hear what is the actual amount of difference.

We receive in fact, on June 30th, less heat and light than dwellers at our antipodes receive on December 30th, by the amount which would be lost if an opaque disk, having a diameter equal to one-fourth of the sun's,[1] came upon the sun's face as seen on December 30th at

[1] It is easily shown that such would be the size of the imagined black disk. For the sun's distance varies from about 93,000,000 miles to about 90,000,000, or in the propor-

our antipodes. It need hardly be said that no spots, whose effects would be comparable with those produced by such a disk of blackness, have ever been seen upon the face of the sun. Spots are not black or nearly black, even in their very nucleus. The largest ever seen has not had an extent approaching that of our imagined black disk, even when the whole dimensions of the spot—nucleus, umbra, and penumbra—have been taken into account. Moreover, all round a spot there is always a region of increased brightness, making up to a great degree, if not altogether, for the darkness of the spot itself. So that unquestionably the summer heat in the Southern Hemisphere exceeds the summer heat in our hemisphere to a much more marked degree than the heat given out by the sun when he is without spots exceeds the heat of a spotted sun.

It is, however, rather difficult to ascertain what effect is to be ascribed to this peculiarity. It is certain that the Australian summer differs in several important respects from the European summer; but it is not easy to say how much of the difference is due to the peculiarity we have been considering, and how much to the characteristic distinction between the northern and southern halves of the earth—the great excess of water-surface over land-surface in the Southern Hemisphere. It is worthy of notice, however, that even in this case, where we cannot doubt that a great difference must exist in the solar action at particular seasons, we find ourselves quite unable to recognize any peculiarities of weather as *certainly* due to this difference.

I have spoken of a second way of viewing the difference in question, by considering it as it affects the whole earth. The result is sufficiently surprising. It has been shown, by the researches of Sir J. Herschel and Pouillet, that on the average our earth receives each day a supply of heat competent to heat an ocean, 260 yards deep over the whole surface of the earth, from the temperature of melting ice to the boiling-point. Now, on or about June 30th the supply is one-thirtieth less, while on or about December 30th the supply is one-thirtieth greater. Accordingly, on June 30th, the heat received in a single day would be competent only to raise an ocean $251\frac{1}{3}$ yards deep from the freezing to the boiling point, whereas on December 30th the heat received from the sun would so heat an ocean $268\frac{2}{3}$ yards deep. The mere excess of heat, therefore, on December 30th, as compared with June 30th, would suffice to raise an ocean, more than 17 yards deep and covering the whole earth, from the freezing-point to the temperature of boiling water! It will not be regarded as surprising if terrestrial effects of some importance should follow from so noteworthy an

tion of 31 to 30. Hence the size of his disk varies in the proportion of 31 times 31 to 30 times 30, or as 961 to 900. The defect of the latter number 900 amounts to 61, which is about a sixteenth part of the larger number. But a black disk having a diameter equal to a quarter of the sun's would cut off precisely a sixteenth part of his light and heat, which was the fact to be proved.

excess, not merely of light and heat, but of gravitating force, of magnetic influence, and of actinic or chemical action, exerted upon the earth as a whole. Accordingly we find that there is a recognizable increase in the activity of the earth's magnetism in December and January as compared with June and July. But, assuredly the effect produced is not of such a character as to suggest that we should find the means of predicting weather, *if* it were possible for us *now* to discover any solar law of change resulting in a corresponding variation of solar action upon the earth.

This leads us to consider the first great law of solar change as distinguished from systematic variations like the sun's varying change of distance and his varying daily path on the heavens. This law is that which regulates the increase and decrease of the solar spots within a period of about eleven years. The sun's condition does not, indeed, admit of being certainly predicted by this law, since it not unfrequently happens that the sun shows few spots for several weeks together, in the very height of the time of spot-frequency, while on the other hand it often happens that many and large spots are seen at other times. Nevertheless, this general law holds, that, on the whole, and taking one month with another, there is a variation in spot-frequency, having for its period an interval of rather more than eleven years.

Now, the difference between a year of maximum spot-frequency and one of minimum frequency is very noteworthy, notwithstanding the exceptional features just mentioned, which show themselves but for short periods. This will be manifest on the consideration of a few typical instances. Thus, in the year 1837, the sun was observed on 168 days, during which he was not once seen without spots, while no less than 333 new groups made their appearance. This was a year of maximum spot-frequency. In 1843, the sun was observed on 312 days, and on no less than 149 of these no spots could be seen, while only 34 new groups made their appearance. This was a year of minimum spot-frequency. Passing to the next maximum year, we find that in 1848 the sun was observed on 278 days, during which he was never seen without spots, while 330 new spots made their appearance. In 1855 and 1856 together, he was observed on 634 days, on 239 of which he was without spots, while only 62 new groups made their appearance. The next maximum was not so marked as usual, that is, there was not so definite a summit, if one may so speak, to the wave of increase; but the excess of spot-frequency was none the less decided. Thus, in the four years, 1858–'61, the sun was observed on 335, 343, 333, and 322 days, *on not one of which he was spotless*, while the numbers of new groups for these four years were, respectively, 202, 205, 211, and 204. The minimum in 1867 was very marked, as 195 days out of 312 were without spots, and only 25 new groups appeared. The increase after 1867 was unusually rapid, since in 1869 there were no spotless days, and 224 new groups were seen, though the sun was only observed on 196 days. The number of spots in 1870, 1871, and 1872, as well as their magnitude and duration, has been above what is usual, even at the period of maximum spot-frequency.

From all this it will be manifest that we have a well-marked peculiarity to deal with, though not one of perfect uniformity. Next to the systematic changes already considered, this alternate waxing and waning of spot-frequency might be expected to be efficient in producing recognizable weather-changes. Assuredly, if this should not appear to be the case, we should have to dismiss all idea that the sun-spots are weather-rulers.

Now, from the first discovery of spots, it was recognized that they must, in all probability, affect our weather to some degree. It was noticed, indeed, that our auroras seemed to be in some way influenced by the condition of the sun's surface, since they were observed to be more numerous when there are many spots than when there are few or none. Singularly enough, the effect of the spots on temperature was not only inquired into much later (for we owe to Cassini and Mairan the observation relating to auroras), but was expected to be of an opposite character from that which is in reality produced. Sir W. Herschel formed the opinion that, when there are most spots, the sun gives out most heat, notwithstanding the diminution of light where the spots are. He sought for evidence on this point in the price of corn in England, and it actually appeared, though by a mere coincidence, that corn had been cheapest in years of spot-frequency, a result regarded by Herschel as implying that the weather had been warmer on the whole in those years. It was well pointed out, however, by Arago, that "in these matters we must be careful how we generalize facts before we have a very considerable number of observations at our disposal." The peculiarities of weather in a single and not extensive country like England are quite insufficient to supply an answer to the wide question dealt with by Herschel. The weather statistics of many countries must be considered and compared. Moreover, very long periods of time must be dealt with.[1]

[1] When Herschel made his researches into this subject, the law of spot-frequency had not been discovered. He would probably have found in this law, as some have since done, the explanation of the seven years of plenty and the seven years of famine, typified by the fat kine and lean kine of Joseph's dream. For, if there were a period of eleven years in which corn and other produce of the ground waxed and waned in productiveness, it would be not at all unlikely that, when ever this waxing and waning chanced to be unusually marked, there would result two series of poor and rich years apparently ranging over fourteen instead of eleven years. We have seen, above, that the waves of spot-waxing and spot-waning are not all alike in shape and extent. Whenever, then, a wave more marked than usual came, we should expect to find it borrowing, so to speak, both in trough and crest, from the waves on either side. It would require but a year or so either way to make the wave range over fourteen years; and observed facts, even during the last half-century only, show this to be no unlikely event.

M. Gautier, of Geneva, and, later, MM. Arago and Barratt, made a series of researches into the tabulated temperature at several stations, and for many successive years. They arrived at the conclusion that, on the whole, the weather is coolest in years of spot-frequency.

But recently the matter has been more closely scrutinized, and it has been found that the effects due to the great solar-spot period, although recognizable, are by no means so obvious as had been anticipated.

These effects may be divided into three classes: those affecting (1) temperature, (2) rainfall, and (3) terrestrial magnetism.

As respects the first, it has been discovered that, when *underground* temperatures are examined, so that local and temporary causes of change are eliminated, there is a recognizable diminution of temperature in years when spots are most frequent. We owe this discovery to Prof. C. P. Smyth, Astronomer Royal for Scotland. The effect is very slight; indeed, barely recognizable. I have before me, as I write, Prof. Smyth's chart of the quarterly temperatures from 1837 to 1869, at depths of 3, 6, 12, and 24 French feet. Of course, the most remarkable feature, even at the depth of 24 feet, is the alternate rise and fall with the seasons. But it is seen that, while the range of rise and fall remains very nearly constant, the crest and troughs of the waves lie at varying levels. After long and careful scrutiny I find myself compelled to admit that I cannot find the slightest evidence in *this* of a connection between underground temperatures and the eleven-years period of sun-spots. I turn, therefore, to the chart in which the annual means are given; and, noting in the means at the lesser depths "confusion worse confounded" (this, of course, is no fault of Prof. Smyth's, who here merely records what had actually taken place), I take the temperatures at a depth of 24 French feet. Now, neglecting minor features, I find the waves of temperature thus arranged: They go down to a little more than 46½ degrees of the common thermometer in 1839–'40; rise to about 47¾ degrees in 1847; sink to 47¼ degrees in 1849; mount nearly to 47¾ degrees again in 1852–'53; are at 47 degrees in 1856–'57; are nearly at 48 degrees in 1858–'59; then they touch 47 degrees three times (with short periods of rising between), in 1860, 1864, and 1867; and rise above 47½ degrees in 1869. Now, if we remember that there were maxima of spots in 1837, 1848, 1859–'60, and 1870, while there were minima in 1843, and in 1855–'56, I think it will be found to require a somewhat lively imagination to recognize a very striking association between the underground temperature and the sun's condition with respect to spots. If many spots imply diminution of heat, how does it come that the temperature rises to a maximum in 1859, and again in 1869? if the reverse, how is it that there is a minimum in 1860? I turn, lastly, to the chart in which the sun-spot waves and the temperature-waves are brought into actual comparison, and I find myself utterly unable to recognize the slightest association between them. Nevertheless, I would not urge this with the desire of in any way throwing doubt upon the opinion to which Prof. Smyth has been led, knowing well that the long and careful examination he has given to this subject in all its details may have afforded ample though not obvious evidence for the conclusions at which he has arrived. I note, also, that, as he points out, Mr. Stone, director of the Cape Town Observatory, and Mr. Cleveland Abbe, director of the Cincinnati Observatory, have since, "but it is believed quite independently, published similar deductions touching the earth's temperature in reference to sun-spots." All I would remark is, that the effect is very slight, and very far from being obvious at a first inspection.

Next as to rainfall and wind.

Here, again, we have results which can hardly be regarded as striking, except in the forcible evidence they convey of the insignificance of the effects which are to be imputed to the great eleven-year spot period. We owe to Mr. Baxendell, of Manchester, the most complete series of investigations into this subject. He finds that, at Oxford, during the years when sun-spots were most numerous, the amount of rainfall under west and southwest winds was greater than the amount under south and southeast winds; while the reverse was the case in years when spots were few and small. Applying corresponding processes to the meteorological records for St. Petersburg, he finds that a contrary state of things prevailed there. Next we have the evidence of the Rev. R. Main, director of the Radcliffe Observatory at Oxford, who finds that westerly winds are slightly more common when sun-spots are numerous than at other times. And, lastly, Mr. Meldrum, of Mauritius, notes that years of spot-frequency are characterized, on the whole, by a greater number of storms and hurricanes than years when the sun shows few spots.

The association between the sun-spot period and terrestrial magnetism is of a far more marked character, though I must premise that the Astronomer Royal, after careful analysis of the Greenwich magnetic records, denies the existence of any such association whatever. There is, however, a balance of evidence in its favor. It seems very nearly demonstrated that the daily sway of the magnetic needle is greatest when sun-spots are numerous, that magnetic storms are somewhat more numerous at such times, and that auroras are also more commonly seen. Now, it has been almost demonstrated by M. Marié Davy, chief of the meteorological division in the Paris Observatory, that the weather is affected in a general way by magnetic disturbances. So that we are confirmed in the opinion that, indirectly, if not directly, the weather is affected to some slight degree by the great sun-spot period.

Still, I must point out that not one of these cases of agreement has any thing like the evidence in its favor which had been found for an association between the varying distance of Jupiter and the sun-spot changes. For eight consecutive maxima and minima this association has been strongly marked, and might be viewed as demonstrated—only it chances, unfortunately, that, for two other cases, the relation is *precisely reversed;* and, in point of fact, whereas the period now assigned to the great sun-spot wave is eleven years and rather less than *one* month, Jupiter's period of revolution is eleven years and about *ten* months, a discrepancy of nine months, which would amount to five and a half years (or modify perfect agreement into perfect disagreement) in seven or eight cycles.

But, accepting the association between weather and the sun-spot changes as demonstrated (which is granting a great deal to the believers in solar weather-prediction), have we any reason to believe that by a long-continued study of the sun the great problem of foretelling the weather can be solved? This question, as I have already pointed out, must not be hastily answered. It is one of national, nay, of cosmopolitan importance. If answered in the affirmative, there is scarcely any expense which would be too great for the work suggested; but all the more careful must we be not to answer it in the affirmative, if the true answer should be negative.

But it appears to me that so soon as the considerations dealt with above have been fairly taken into account, there can be no possible doubt or difficulty in replying to the question. The matter has, in effect, though not in intention, been tested experimentally, and the experiments, when carried out under the most favorable conditions, have altogether failed. To show that this is so, I take the position of affairs before Schwabe began that fine series of observations which ended in the discovery of the great spot-period of eleven years. Let us suppose that at that time the question had been mooted whether it might not be possible, by a careful study of the sun, to obtain some means of predicting the weather. The argument would then have run as follows: "The sun is the great source of light and heat; that orb is liable to changes which must in all probability affect the supply of light and heat; those changes may be periodical, and so predictable; and, as our weather must to some extent depend on the supply of light and heat, we may thus find a means of predicting weather-changes." The inquiry might then have been undertaken, and undoubtedly the great spot-period would have been detected, and with this discovery would have come that partial power of predicting the sun's condition which we now possess—that is, the power of saying that in such and such a year, taken as a whole, spots will be numerous or the reverse. Moreover, meteorological observations conducted simultaneously would have shown that, as the original argument supposed, the quantity of heat supplied by the sun varies to a slight degree with the varying condition of the sun. Corresponding magnetic changes would be detected; and also those partial indications of a connection between phenomena of wind and rain and the sun's condition which have been indicated above. All this would be exceedingly interesting to men of science. *But*, supposing all this had been obtained at the nation's expense, and the promise had been held out that the means of predicting weather would be the reward, the non-scientific tax-paying community might not improbably inquire what was the worth of these discoveries to the nation or to the world at large. Be it understood that I am not here using the *cui-bono* argument. As a student of science, I utterly repudiate the notion that, before scientific researches are undertaken, it must be shown that they will *pay*. But it is one thing to adopt this mean and contemptible view of scientific research, and quite another to countenance projects which are based *ab initio* upon the ground that they will more than repay their cost. Now, I think, if the nation made the inquiry above indicated, and under the circumstances mentioned, it would be very difficult to give a satisfactory reply. The tax-payers would say: "We have supplied so many thousands of pounds to found national observatories for the cultivation of the physics of science, and we have paid so many thousands of pounds yearly to the various students of science who have kindly given their services in the management of these observatories; let us hear what are the utilitarian results of all this outlay. We do not want to hear of scientific discoveries, but of the promised means of predicting the weather." The answer would be: "We have found that storms in the tropics are rather more numerous in some years than others, the variations having a period of eleven years; we can assert pretty confidently that auroras follow a similar law of frequency; southwest winds blow more commonly at Oxford but less commonly elsewhere, when the sun-spots, following the eleven-year period, are at a maximum; and more rain falls with southwesterly winds than with southeasterly winds at Oxford and elsewhere, but less at St. Petersburg and elsewhere, when sun-spots are most numerous, while the reverse holds when the spots are rare." I incline to think that, on being further informed that these results related to averages only, and gave no means of predicting the weather for any given day, week, or month, even as respects the unimportant points here indicated, the British tax-payer would infer that he had thrown away his money. I imagine that the army of observers who had gathered these notable results would be disbanded rather unceremoniously, and that for some considerable time science (as connected, at any rate, with promised "utilitarian" results) would stink in the nostrils of the nation.

But this is very far, indeed, from being all. Nay, we may almost say that this is nothing. Astronomers *know* the great spot-period; they have even ascertained the existence of longer and shorter periods less marked in character; and they have ascertained the laws according to which other solar features besides the spots vary in their nature. It is certain that whatever remains to be discovered must be of a vastly less-marked character. If, then, the discovery of the most striking law of solar change has led to no results having the slightest value in connection with the problem of weather-prediction, if periodic solar changes of a less marked character have been detected which have no recognizable bearing on weather-changes, what can be hoped from the recognition of solar changes still more recondite in their nature? It is incredible that the complex phenomena involved in meteorological relations regarded as a whole, those phenomena which are but just discernibly affected by the great sun-spot period, should respond to changes altogether insignificant even when compared with the development and decay of a single small sun-spot. It appears to me, therefore, that it is the duty of the true lover of science to indicate the futility of the promises which have been mistakenly held out; for it cannot be to the credit of science, or ultimately to its advantage, if government assistance be obtained on false pretences for any branch of scientific research.

ORIENTALS AT VIENNA.

THE anticipations with regard to the appearance made by Orientals at Vienna will be realized to the full, and doubtless the contact between the East and West will prove of mutual advantage. In fact, the peculiarly happy situation of the Austrian capital has not only given this Exhibition its distinctive character, but has developed its proportions in a degree that has falsified all the original calculations. It soon became evident that circumstances would take it out of the category of those which had preceded it; that it might open new markets which were practically limitless, and that it would throw new and valuable lights upon hackneyed and familiar subjects. It was seen that it would reproduce, on an immeasurably greater scale, such cosmopolitan gatherings of traders as assembled at the great fairs of Leipsic or Nijni-Novgorod; that it would drag into open day the rarer contents of Oriental bazaars, and expose them side by side with the goods produced in Western manufactories and sold by Western shopkeepers. There would be unrivalled opportunities of making comparisons and drawing conclusions, of learning practical lessons and exploding antiquated prejudices. So it seems likely to prove; nor will either half of the world have much reason to triumph over the other. We need not advertise the wonders of our Western civilization. If we are not much in the way of boasting of them as against the benighted East, it is simply because we enjoy the serene self-complacency of indisputable superiority. To a certain extent we are justified by the results of a rapidly-accelerating progress, which shows itself in the swift growth of our material prosperity. We work at the highest pressure; we invoke science to our assistance, and foster a restless rivalry that drives invention forward at express speed; we multiply labor by the introduction of mechanical improvements; and we supply our homes with luxuries that have become necessaries at extraordinarily economical rates. In short, we produce quickly and cheaply, and in all that relates to action we leave the dreamy East immeasurably behind, as the Easterns are ready enough to acknowledge, and, for the most part, rather with commiseration than envy. But, on the other hand, in much that is highest and most perfect in art we are the scholars and they the teachers. Our best-informed and most experienced technical and practical men are the most ready to acknowledge this. It is not wealthy connoisseurs and capricious *dilettanti* who lounge about the courts of Japan, China, and Turkey, cheapening the strangely attractive wares which are exposed by the merchants from those distant countries. It is the European manufacturers and tradesmen—especially the English—who rush into the Eastern departments, eagerly bidding against each other for every thing that strikes their fancy. This is one of the most characteristic features of the Vienna Exhibition. On no previous occasion of the kind has there been such wholesale buying and selling in the very earliest days, and the traffic goes forward most briskly in the Oriental quarters. As yet, Japan has not cleared her goods at the custom-house; China has scarcely imported the better part of hers. Those countries cannot as yet pretend to set a price upon their wares, while the prices fixed by the Persians seem high enough in all conscience, and the Ottomans are following suit after the time-honored fashion of Eastern dealers. Yet already the choicest of the Persian prayer-carpets are snatched up at the high prices set upon them; the best of the Japanese porcelain, bronzes, *cloisonnée* ware, and silks, have been sold several times over, the charges being left to the conscience of the commissioners, and the cards of the fortunate purchaser lying on the fragments of the torn tickets that had been affixed by rejected bidders; while even in Turkey and Tunis, which come far behind Japan and Persia in taste and quality of workmanship, many of the goods have changed owners already, the Prince of Wales being among the earliest and most considerable buyers.

The truth is, the more closely we look into the special productions of the East, the more we recognize its incontestable superiority in design and color, and in perfection of form and finish. The Orientals have plenty of time, no doubt, and do not grudge it; they can afford to work leisurely and carefully where we must economize labor by the rapidity of our processes and the multiplying power of our machinery. But then they have taste as well, and a taste which is older than schools of art, and seems nearly independent of technical education. Compare the graceful turbans and draperies of the Oriental with the stiff "chimney-pot," cutaway, and trousers of the Frank. The latter, although open to criticism even as convenient wear, doubtless look more like business. They give the idea of stripping easily for a hard day's work, and suggest readiness to answer the calls of any emergency. They are turned out comparatively cheaply to cut-and-dry patterns. The former are the signs of a languid yet not unfruitful existence. But they express the intuitive gracefulness of ideas evolved in a calm fulness of thought that will not be hurried; they show an originality and versatility of fancy whose inspirations may have been sought in the dreamy fumes of opium. Go to the remotest East of Asia, seek the Oriental on his own proper ground, and you seldom take him at a disadvantage. In his own unpretending way, the peasant who weaves mats of bamboo or moulds vessels of common clay in his retired village is as much of an artist as the skilled workman of Yeddo who lacquers cabinets in the most delicate plaques of veneer, or chases the bronze incense-burners that are to swing in the temples. When the Oriental breaks down is when he takes to imitating the European, as he has begun to do in these latter days. The Japanese sometimes turn from their own beautiful specimens of Kago and Satsuma porcelain to reproduce the fashions and colors of Parisian and English crockery, while the Turks back their clumsy machinery against the looms of Manchester in calicoes and cottons. Happily these follies of imitation are as yet rare; and probably the profits of this novel trade will not encourage the enterprising imitators to persevere. The East has much to learn from the West, and the lessons that will prove of most service to it go to the very groundwork of its society. It has yet to be enlightened as to the advantages of civil and religious liberty and education, the value of time, and the necessity of system and method. All this it is now learning, and in some matters of detail its education is going on only too rapidly. Doubtless sooner or later it will come to our markets for machinery which will enable it to make at home what it imports at present from abroad. But some of its tentative advances in this direction are premature and injudicious, to say the least, and, judging by certain samples of its imitative skill, it seems inclined to precipitate a competition whose unfortunate results in price and quality may cause it permanent discouragement.

However, it is not our purpose now to discuss the points on which we may teach the Orientals, but rather to glance at some of those where we are the scholars. There is a great deal in the Eastern departments of the Vienna Exhibition which is chiefly interesting as showing their relative backwardness. Some of them, for instance, send complete samples of their cereals and vegetable productions, and and these are curious as illustrating the advantages of soil and climate which yield them, in spite of the most backward husbandry and the most primitive implements, returns of twenty, fifty, or a hundred fold. But only turn to their show in the arts, and some of them may almost set criticism at defiance. By general consent, and beyond all comparison, the first place must be assigned to Japan. The Japanese does most things unlike the rest of the world. His method of handling his tools is precisely the opposite of ours. He draws his plane toward him, works his saw in the reverse direction, taps with the side of his queer hammer, and handles his quaintly-chased graving tool in a way at which an English workman would stare. Yet, whether he is laying the shingles on the roof of a cottage, or chasing one of those wonderfully elaborate caskets in metal-work, what English workman can approach him? His ideas discover an endless originality; individual impulse, rather than education, seems to inspire his fancy, although it may work according to received traditions of the quaint or beautiful; and, look where we will through a most miscellaneous collection, we can scarcely see a trace of servile repetition. In his pictorial art he can convey a world of expression and suggestion in the very smallest number of touches. Yet when it pleases him to finish, as when he is painting on his delicate porcelain, he is scarcely to be surpassed in harmonious minuteness. As for his colors, you may puzzle out his secret if you can; at least he shows you in an open case the chemicals which, as he professes, form his ingredients. All that can be said is, that none of the numerous attempts at imitation have ever proved to be any thing approaching a success. That strange superiority in color, not only in the tints, but in their management, is to be remarked in every one of the Oriental courts. The silks of China excel even those of Japan, in their bright blues and gorgeous crimsons; while, for softened brilliancy and exquisite delicacy of blending, the Persian carpets are confessedly unequalled. The invariably subdued beauty of these patterns argues something more than great mechanical perfection in the arts of color-making and dyeing. It is proof of a general purity of taste on the part of the Oriental purchasers for whom the fabrics were originally intended; for, although many of the best may now be consigned to Europe, the manufacture, precisely as we see it, has been practised from time immemorial; there are carpets in the Exhibition called modern by comparison, although they may date back for a century or so, and these are of patterns exactly similar to the latest ones. In every thing exhibited from China and Persia, the work is almost invariably good, and the designs felicitous; although, except in certain specialties, they cannot vie with Japan, yet every now and then one stumbles upon something that is extremely beautiful in art. So much can hardly be said of Turkey. Turkey makes a very imposing display; the Sultan contributed £100,000 toward forming the collection, and some of the great merchants in Constantinople, Smyrna, and elsewhere, have apparently done their best to advertise themselves. There is a good deal shown in Turkey, as well as in Tunis, that would have attracted great admiration had there been no Japan and no China to provoke unfavorable comparison. The famous Turkey carpets can scarcely be said to be satisfactorily represented. The very best, beautiful as the texture is, fall far short, even in that respect, of the Persian; while the contrasts displayed in the body of the Turkish patterns are too often disagreeably violent. But for the most part the carpets exhibited are of a very ordinary class indeed. The inlaid *marqueterie* and cabinet-work seems rude in design and coarse in execution, if we measure it against the Japanese standards. The carved olive-wood from Jerusalem recalls the pedlers' hawking goods made for sale at the doors of the Holy Sepulchre. Here and there are some exquisite arms among many that are inferior; but even the very best of them are excelled by the Persians. There are graceful shapes in the pottery, but they are not unfrequently marred by defects in the workmanship. There is a great collection of figures in the various national costumes, and the dresses strike one as being somewhat incongruous. On the whole, the only articles in which Turkey may be said to show to decided advantage are some extremely rich furniture stuffs, the choicest of which seem to have been already sold or removed, and the dyed morocco, which, in its vividness of color, shames any thing that can be shown by the West. It must be remembered, however, that the Turk gives almost as many months to the dyeing process as the European allows days. Taste apart, we may perhaps console ourselves for the inferiority which we must confess by repeating that facts like this deliberate process of dyeing furnish the key to much of the Oriental excellence. Time is of no value in the East, and patience and indefatigable perseverance have always been the willing handmaids of their arts and manufactures.—*Saturday Review.*

THE MORBID EFFECTS OF HEAT.

By WM. J. YOUMANS, M. D.

THE healthy human body has a temperature which varies but little either way from 99° Fahr. The heat required to maintain this temperature is derived from the oxidation within the body of the elements of the food. In other words, our bodies are furnaces; the food we take is the fuel which supplies the furnace, and the air we breathe is the draught that keeps the combustion going. The amount of heat thus evolved is, in health, always in excess of that needed to maintain the required temperature. There is, therefore, a constant overplus, a part of which is converted into mechanical work, while the remainder escapes as waste, partly along with the matters passing out of the body through the lungs, kidneys, and skin, and partly by the processes of conduction and radiation.

In estimating the morbid effects of external heat upon the living body, this waste requires to be taken into account, as its fluctuations, through the operation of surrounding conditions, have much to do with the regulation of the body-temperature. If, by exposure to cold, for example, heat is lost more rapidly from the surface than it is supplied within, its warmth must decrease, and there needs but a few degrees of fall to induce disease; on the other hand, if, by exposure to external heat, loss from the body is impeded, its temperature rises, and disease again results.

In hot climates, or during the hot season in temperate latitudes, we are in contact with an atmosphere which frequently attains a temperature nearly or quite equal to that of the body; and, at such times, our sensations tell us that we are losing heat less easily than during the cooler portions of the year. But, when thus exposed, the extensive evaporating surfaces of the lungs and skin are called into more active play; and, if the air is of average dryness, heat is rapidly thrown off by perspiration, the loss being so nicely adjusted that a uniform temperature of 99° Fahr. is continuously maintained. This heat-regulating function of the organism is one of the marvels of physiology. In spite of the vicissitudes of climate and season, it ever holds the temperature at a uniform degree, and, even under the stress of high artificial heat, is able to keep the balance comparatively unchanged. Blagden and Fordyce exposed themselves in an oven to a heat of 260° Fahr., without serious inconvenience, and with but a slight rise of temperature. But the air was dry, and the heat was kept down by perspiration. The substitution of moist for dry air in the oven hindered evaporation, and the temperature of the body rose rapidly. With this hasty sketch of the heat-producing and heat-regulating functions of the animal economy, we pass to a brief consideration of some of the more important ill-effects resulting from the action of excessive heat on the conditions of health and on the body itself.

High temperature is a powerful aid to decomposition. Dead organic matter, under its influence, speedily decays, giving rise to foul and poisonous products which, escaping into the atmosphere, find their way, sooner or later, into the system. Here they work various forms of mischief. Like sulphuretted hydrogen gas, they may be directly poisonous, or, like carbonic-acid gas, may act by diluting the air, and so, by reducing the normal supply of oxygen, interfere with the due oxygenation and purification of the blood. The filth of towns is always highly charged with organic matter, and this, when rapidly decomposing in the heats of summer, has long been recognized as a prolific source of disease.

Decaying vegetable matter in the soil is held to be the source of malarial poison; and here, again, if moisture is present, decay is always hastened and increased by excessive heat. So great, in the opinion of Dr. Parkes, is the influence of heat on the development and spread of malarious disease, that, in selecting a residence with a view to escaping its effects, he recommends that, in tropical countries, the point be 1,000 or 1,500 feet higher above the source of the poison than is required in temperate latitudes. The remittent form of malarious fevers, according to Dr. Maclean, "is most prevalent and fatal where high temperatures and malaria act in combination." The same authority also says: "I have, in a great many instances, observed intermittents pass at once into a severe type of the remittent form, apparently from no other cause than the descent from comparatively cool and elevated regions into the heated plains, and this under circumstances where there was no reason to believe that the sufferers had been again exposed to malaria."

In the production and spread of cholera, and yellow fever, excessive heat also has an important share. Both are most intimately associated with decomposing filth; both are conveyable by the putrefying stools of the sick, and both flourish most in hot climates and hot seasons. In the case of cholera, the bad effects of extreme heat are abundantly shown by what has been observed in the tropics. "In Bengal," says Dr. Goodeve (Reynolds's "System of Medicine," vol. i., p. 129), "the hot seasons, including the hot, and dry, and rainy seasons, have witnessed the worst epidemics." The most fatal cholera months, in both tropical and temperate countries, are found between April and September. Among European troops in Bombay, according to Dr. Ewart's tables, which cover a period of eight years, more than 50 per cent. of the cases treated in the six months from April to September died, while but little over 19 per cent. of the cases treated in the other six months of the year were fatal. That the disease occurs in winter is undoubted, but that it is much less general and severe is equally true. Yellow fever, though resembling cholera in many ways, is unlike it in this—a temperature of 70° or 72° Fahr. is absolutely requisite to its development and propagation, and the occurrence of frost at once puts an end to its ravages.

Heat also contributes largely toward the production of diarrhœa, its more common form, in recognition of this, taking the name of summer complaint. The disease is far more common and more fatal in hot than in cold climates, and in the summer season of temperate climates than in the winter. Putrefying organic matter, held in suspension in drinking-water, is, according to Dr. Parkes, one of the most common causes of diarrhœa, and this condition of the water is very frequent in summer, and comparatively rare in winter.

In all these instances heat appears to act not so much upon the body itself as upon the various external agencies influencing health. It is to bad conditions what fire is to powder. If the match is withheld, the powder is harmless; but, as the two are liable to come together, we secure safety by removing the magazine. So the presence of filth in water, in soil, and above-ground, may be innocuous by itself, but let the action of heat touch it off into decomposition, and we at once get the effects in the shape of disease. Heat thus aids the pollution of both air and water, keeps alive and active the germs of disease in the excreta of the sick, and in both ways favors the spread of contagion.

Its direct action upon the person becomes most apparent when some of the functions are going wrong. When the body is healthy, and proper precautions are taken in its management, there is little to fear from exposure to heat. Observers in tropical countries tell us that excessive heats are borne with impunity by the healthy, and that it is mostly those who are either temporarily or chronically out of order that eventually suffer. Not that the body can bear unlimited exposure to great heat, any more than it can endure continuous exertion, but that it is capable of maintaining itself under even excessive heat, if the exposure is not too prolonged. When its powers are impaired by some local or constitutional complaint, however, and it is less able to do the extra work which the influence of excessive heat imposes, then is the time when even slight exposure may be followed by the most serious consequences.

Authors describe several forms of acute disease that are traceable to heat as the exciting cause, but, as all of these partake more or less of the nature of sunstroke, and as we are writing for the public rather than the physician, it is not necessary here to go into their distinguishing features. Sunstroke, or the disease hitherto passing under that name, though known since early times, is even yet not well understood. Up to within a few years, it was believed by patient and physician alike that, to produce it, the body, and especially the head, must be exposed to the direct rays of the sun. There is now abundance of proof to the contrary. In his admirable little work, entitled "Thermic Fever, or Sunstroke," Dr. H. C. Wood quotes the records of its occurrence in barracks, hospitals, and tents, and not infrequently in the night-time, in many cases without immediate previous exposure to the sun. According to Dr. Bonnyman, as cited by Dr. Wood, "By far the greater number of cases that yearly occur in India are of men who have not been exposed to the sun. It is not unusual for men to go to bed in apparent health, and to be seized during the night; and patients in hospitals, who have been confined to bed for days previously, are frequently the subjects of attack." Dr. Swift testifies to its production by exposure to artificial heat, eleven cases treated by him having been attacked in the laundry of an hotel; while several others occurred in sugar-refineries. Dr. Wood mentions a case of his own, which also originated in a sugar-refinery. Dr. Maclean, in the second volume of Reynolds's "System of Medicine," quotes M. Boudin to the effect that one hundred cases of sunstroke occurred on the French man-of-war Duguesne at Rio Janeiro, most of them at night while the men were lying in their bunks. Much more of similar import might be offered, but enough has been said to show that it is great heat which precipitates the attack, and that it makes little difference whether this come from exposure to the direct rays of the sun, or from a highly-heated atmosphere, or indeed from some artificial source.

But while heat is rightly regarded as the principal if not the sole exciting cause, there are other conditions, as previously stated, which contribute largely toward bringing on the attack. Of these, overcrowding, and its associate, insufficient ventilation, are among the most important. The histories of the outbreaks that have occurred in barracks, in tents, and on shipboard, refer to these conditions as always present, and also mention that both officers and men in every other way similarly circumstanced, but provided with plenty of room and ventilation, did not suffer.

Another and equally important predisposing cause is the exhaustion produced by prolonged exertion. The fact that a large proportion of the cases occurring in this country are of persons engaged in laborious occupations is evidence of this, and if more is needed it is found in the experience of army-surgeons in India, who state that some of the severest epidemics ever witnessed in that country took place among the troops toward the close of long and fatiguing marches, when not a case was observed while the men were fresh and vigorous.

Want of acclimatization is set down as another powerful predisposing cause. "Foreigners," says Dr. Wood, "are always attacked in much larger numbers than natives of the tropics. It must be remembered, however, that no amount of acclimatization will afford certain protection, as even the Hindoo, born and bred in the stifling air of Bengal, is occasionally attacked.

Tight-fitting clothing, which impedes the circulation and hinders the movements of the body, likewise invites attack. Formerly soldiers in India were dressed, in the hottest weather, with tightly-buttoned coats, stiff leather stocks, heavy cross-belts over the chest, and a cap peculiarly adapted to concentrate the rays of the sun upon the head. When so accoutred, according to the testimony of their medical officers, sunstroke among them was common; and, since this style of dress has been done away with, it is much less frequent.

Persons addicted to spirit-drinking are by many writers believed to furnish a much larger proportion of cases than abstainers.

The presence of a large amount of watery vapor in the air is held, by Parkes and others, to predispose to sunstroke. By opposing evaporation from the surface, it favors the rise of animal temperature.

Other causes predisposing to sunstroke are given by different writers; they are, however, of the same general nature as those already enumerated, being simply conditions which either diminish the powers of the system, or for the time being impose upon them some heavy tax. Whether death from sunstroke is due to the action of heat on the nervous system, or to the coagulation of the muscle-plasma (myosin) of the heart, or to blood-poisoning, or in some cases to one, and in others to another of these causes, as maintained by different physicians, it is not necessary here to inquire. What chiefly concerns us now, having pointed out the principal causes of the disease, is to learn something of its symptoms, how in the absence of the doctor it should be treated, and what to do to avoid it.

The serious disturbance of all the functions occasioned by sunstroke results, as might be expected, in a great variety of symptoms. In a small proportion of cases, however, the attack is so sudden and so quickly fatal that little chance for the development or observance of symptoms is afforded. The patient suddenly falls, gasps a few times, and dies. But, in the majority of instances, premonitory symptoms are present. The more constant, as given by the best authorities, are great heat and dryness of skin, a varying degree of pain in the head, attended oftentimes with giddiness, congestion of the eyes, full, rapid pulse, which grows feeble and irregular as the disease advances, obstinate constipation, irritability of bladder, and great oppression or sense of weight about the region of the heart, with not unfrequently muscular weakness and a disinclination for exertion. If these symptoms continue, the patient soon passes into a state of profound insensibility. The pupils fail to respond to the action of light, and may be somewhat contracted, the breathing becomes hurried and difficult, and the action of the heart is irregular and tumultuous. Convulsions may come on early, or be postponed until late in the disease, or they may be absent altogether. Numerous minor and less constant phenomena have been recorded by different observers; but, when a person is suddenly attacked during exposure to great heat, the symptoms already enumerated will enable any one of ordinary intelligence to recognize the true character of the disease.

Only such measures of treatment will be suggested as any one of common-sense can apply; and they may be the means, if promptly resorted to, of ultimately restoring the patient, when, if nothing were done until the physician arrived, he might then have passed beyond the reach of help.

When the signs of an attack appear, the sufferer should be immediately taken to the nearest shade, preferably in the open air, but, at all events, where the freest ventilation can be secured. His body should at once be stripped, and the head, neck, and chest, continuously drenched with cold water. Let this be followed up, not timidly, but with boldness, until respiration is reëstablished, after which it may be applied at short intervals, until a perceptible diminution of the temperature of the body has taken place, or until the doctor arrives. It is the great heat of the body that menaces life, and, the sooner this can be reduced into the neighborhood of the natural temperature, the better for the patient. In rare instances this free use of cold water, by the powerful impression it makes on the nervous system, excites convulsions, in which case it may be discontinued, and rubbing the surface with pounded ice resorted to. An injection of ice-cold water,

JAMES H. COFFIN.

as recommended by Dr. Parkes, may, at the same time, be given. When he can swallow, the patient should be encouraged to drink freely, and, if vomiting follows, so much the better, as this tends to relieve the lungs, which are always greatly congested. Other measures of treatment, and the management of after-consequences, may be most safely left in the hands of the physician.

After what has been said, the means to be adopted for the avoidance of sunstroke will readily suggest themselves. Great care must be taken to preserve intact the function of the skin, and nothing is better for this than frequent bathing, and friction of the surface. Hard labor, in a close, highly-heated atmosphere, or during extreme hot weather, in the sun, should be carefully shunned, and the use of spirits, if previously indulged in, entirely discontinued. The dress should be such as will permit free loss of heat, preferably linen, and on no account should it be so close fitting as to hinder the motions of the chest, neck, or head. A light hat, permitting free circulation of air about the top of the head, is very useful. English troops in India wear light wicker-helmets made of bamboo, and covered with cotton. These permit thorough ventilation of the head, and, according to Dr. Parkes, have diminished the frequency of sunstroke.

SKETCH OF PROFESSOR COFFIN.

FROM Sir Richard Coffin, Knight, who accompanied William the Conqueror to England in 1066, springs the genealogical tree that bears the name of Tristram Coffin, the pioneer owner of the island of Nantucket, whose American descendants have been engaged, to a large extent, in navigation. Of these, and fifth in line of descent from Tristram, is the subject of this sketch.

Prof. JAMES HENRY COFFIN, LL. D., was born in Williamsburg, Mass., on the 6th day of September, 1806. He was, therefore, sixty-six years old at the time of his decease, which occurred February 6, 1873, at Lafayette College, Easton, Pa., where he had long filled the professorship of Mathematics and Astronomy. He graduated at Amherst College in 1828, and the year following established, at Greenfield, Mass., the Fellenberg Manual Labor Institution, which for eight years continued to be one of the rarely successful instances of this system in our country. He subsequently became the Principal of the Ogdensburg (N. Y.) Academy, and, in 1839, a member of the Faculty of Williams College. In 1846 he became Professor of Mathematics in Lafayette College. In the interests of this institution he labored zealously till the close of his life, being rewarded by seeing it rise to its present high rank among our colleges.

As a teacher he was laborious and enthusiastic, and his success was remarkable. He secured the respect and love of his pupils to a degree seldom equalled; but he was also a zealous student in science, and published several valuable works as the results of his researches. Among these are his "Analytical Geometry," and his "Conic Sections," which, at one time, were extensively used as text-books in our colleges. While connected with the Fellenberg Institution, he published two works on book-keeping, that were adopted by the State schools of Massachusetts. He read many valuable papers before the American Association for the Advancement of Science, of which he was, from its organization, a member; and also before the National Academy of Science, for the recent meeting of which he had in preparation an article on the Storm-curve, the object being to show that it was an hyperboloid, the equation of which he had computed.

His chief reputation, in science, was achieved by his researches in the department of meteorology. These were commenced in 1839, while Principal of the Ogdensburg (N. Y.) Academy. He took simultaneous and constant observations of the barometric changes connected with the variations of the wind-vane and with the fall of rain. His instruments were self-registering. Each motion of the vane directed a minute but constant stream of dry sand into some one of 32 stationary hoppers, corresponding in position to as many points of compass. The weight of sand found in the several receptacles below each hopper showed the length of time that the vane had pointed in that direction. The rain-gauge was an inverted cone, having an horizontal surface of 172.8 square inches: the rain falling into it passed down, through an orifice so small that no appreciable evaporation could occur, into a close-fitting can. One inch of rain in depth would, therefore, make $\frac{1}{10}$ of a cubic foot when collected, the weight of which is 100 ounces. Each ounce that the can contained after a storm, consequently, represented $\frac{1}{100}$ of an inch in perpendicular fall. The amount necessary to merely moisten the funnel without precipitation into the can is easily determined as a constant. The results of these observations for the year 1838 were published by Prof. Coffin in the *Meteorological Register*, a monthly journal, of which he issued the first number in January, 1839. It was devoted to the discussion of various phenomena connected with physical science. Though the demand for a periodical of this nature was insufficient to sustain it, it brought into correspondence many who were interested in such subjects. The investigation of rainfall and evaporation had present practical value in being made the basis of the report of the committee of the New York Senate, in 1839–'40, appointed to consider the enlargement of the canal system of the State by the construction of the Genesee Valley Canal. These studies were afterward extended to form the chapter on the climate of the State, published in the "Natural History of New York," in 1845, in which the inquiries took a wider range; and questions of vegetation, agricultural epochs, the migration of birds, etc., were introduced. A determination was also made of the amount of rise in the thermometer per hour, during the prevalence of winds from the northeast by east to south-southwest, and the unequal corresponding decrease of temperature when the winds were from the northwesterly points of compass.

While at Williams College, Prof. Coffin erected, upon the Greylock peak of Saddle Mountain, at a height of nearly 4,000 feet above the ocean, an observatory, where continuous observations were taken, even through the winter season, when for three months it was impracticable to ascend the peak. In this interval the clock-work faithfully did its entire duty. The anemometer had been changed by substituting for the stream of sand a series of cards half an inch square, laid consecutively on a moving band that deposited one of them every fifteen minutes. Each card being inscribed with the day and hour it represented, when the receptacle marked "North," for example, was examined, all the cards found in it indicated the exact quarter-hour in the past three months when the wind was from that direction. In 1872 he constructed, for the observatory of the Argentine Confederation, at Cordova, a duplicate of this instrument, with improvements by John M. Junkin, M. D., similar to the one in use at Lafayette College.

The "Results of Meteorological Observations for 1854–'59," in two volumes, quarto, 1757 pages, prepared under his supervision, under the auspices of the Smithsonian Institution, constitute a vast fund of condensed material from which to study the climate of North America.

But the great work of Prof. Coffin's life was the development of his theory of the winds, under the auspices of the Smithsonian Institution, the following account of which has been furnished us by Prof. Henry, Secretary of the Institution:

The results of the scientific labors of Prof. Coffin include contributions to astronomy, mathematics, and especially to meteorology. His labors in regard to the latter branch of science commenced immediately after his graduation, and were continued, almost uninterruptedly, until the time of his death. He was early recognized as one of the meteorologists of the country, and, on the establishment of the Smithsonian Institution, he was invited to become one of its collaborators in that line. All the materials which were collected from the observers of the Institution, and from those of the army from 1854 to 1859 inclusive, were placed in his hands for reduction and discussion. This work was conscientiously and thoroughly performed, and the results published in a quarto volume of upward of 1200 pages. In conducting this work, Prof. Coffin engaged the services of some of the students of Lafayette College, and a large number of women. The wages of these computers were paid by an appropriation from Congress, while the services of Prof. Coffin himself, in directing and superintending the whole, were entirely gratuitous.

But the great work to which he owes his celebrity, in all parts of the world, is his treatise on "The Winds of the Northern Hemisphere," published in the "Transactions of the Smithsonian Institution," vol. vi., in 1853. This work had been commenced at least ten years before the date of its publication, a communication having been made in relation to it to the American Association for the Advancement of Science, in 1848.

The materials on which it was based were derived from all accessible sources, including 600 different stations on land, and numerous positions at sea, extending from the equator to the 83d degree of north latitude, the most northerly point ever reached by man, and embracing an aggregate period of over 2,800 years.

The design of the work was to ascertain, as far as possible, the mean direction in which the lower stratum of the air moves in different portions of the Northern Hemisphere, its rate of progress, the modification it undergoes in different months of the year, the amount of deflecting forces, and its relative velocity from different points of the compass. The collection of this material involved an amount of correspondence and bibliographical research which but few would undertake, even with the hope of pecuniary reward, and still fewer for the love of truth, and the acquisition of knowledge for its own sake. But the labor of computation, and discussion of the materials, was an almost Herculean task, to which years of silent and unobtrusive labor were devoted. The work consisted mainly of about 140 quarto tables of figures, with descriptive deductions, and illustrated by maps. Each of these figures is the result of laborious calculations, since the method of determining the velocity and direction of the wind is the same as that employed by the mariner in determining the distance in a straight line, and direction at the end of a given time, from the place of his departure. In this work Prof. Coffin was the first clearly to establish the fact, by accurate comparison of observations, that there are three great zones of winds in the Northern Hemisphere. The first belt is that of the region of the easterly trade-winds, extending northward in the Western Hemisphere to about the 32d degree north latitude, and in Europe to the 42d degree. The second is the great belt around the world of the return-trades, in which the predominant direction is from the west. This extends northward in America to 56°, and in Europe and Asia to about 66° north latitude. Beyond this, principally within the Arctic Circle, is a belt of easterly or northeasterly winds. The common pole of these belts or zones has not the same position as that of the geometrical pole of the earth. It appears to be in latitude 84° and longitude 105° west of Greenwich, and has been denominated by Prof. Coffin the meteorological pole.

These results are in general accordance with the mathematical deductions from the theory of the winds of the globe, which considers them as due to the combined action of the movement produced in the air by the greater heat of the equator, and the rotation of the earth on its axis.

The researches of Prof. Coffin also strikingly exhibit the fact of the influence of the seasons in modifying the direction of the wind, or in producing the results denominated monsoons. Thus, along the eastern coast of North America, as is shown on the maps, the tendency during the summer months of the opposing forces is to lessen the dominant westerly wind, and this effect is noticed even beyond the Mississippi, as well as in the Atlantic Ocean along our coast. The effect is, undoubtedly, due to the change of temperature in the land—the temperature of the ocean remaining nearly the same during the year, while that of the land is greatly increased in summer above the mean, and depressed in winter. From this cause the air will tend to flow toward the centre of the continent from the ocean in summer, and from the same centre toward the ocean in winter.

The results of the investigations of Prof. Coffin have been referred to in all the treatises on meteorology which have appeared since their publication, and they have been employed with other materials as the basis of the wind-charts of the Atlantic and Pacific Oceans, prepared and published by the English Board of Trade.

In attentively studying the result of Prof. Coffin's labors, we cannot but be struck with his conscientious regard for accuracy, and his devotion to truth. In all cases in which the results do not conform to the theory which explains the general phenomena, the discrepancies are fully pointed out; and, where he is unable to suggest an hypothetical cause of the anomaly, he candidly acknowledges his ignorance. In this respect he is an admirable example of a successful investigator, since errors in science as frequently occur from defects of the heart as from those of the head.

After the publication of the work on the winds, he continued to collect materials, at first with a view to an appendix, and finally extended his investigations to the winds of the entire globe. To aid in this enterprise, the Smithsonian Institution placed in his hands all the observations on the winds, which it had obtained from its numerous observers during the twenty years since the system was commenced, together with the observations made by the officers of the army, as well as the extensive series of materials in the various series of transactions of scientific societies of the Old World, obtained through the exchanges of the Institution. This work, for several years past, Prof. Coffin prosecuted with unremitting assiduity during all the intervals which could be spared from his laborious professional duties. Unfortunately, however, he was not spared to complete the work, although it is in such a condition as to be readily finished under the direction of the principal assistant employed by Prof. Coffin. It is expected that the tables will all be completed during the present summer, and that the printing of the work will be commenced next autumn.

In reviewing what may be called the extra labors of Prof. Coffin, we cannot refrain from endeavoring to impress upon the mind of the general public that men of his character, who do honor to humanity, ought not to be suffered to expend their energies in the drilling of youth in the mere elements of knowledge, and with a compensation not more than sufficient to secure the necessaries of life; that they should be consecrated as officiating priests in the temple of knowledge, be furnished with all the appliances and assistance necessary to the accomplishment of their objects, namely, the extension of the bounds of human thought and of human power.

The premature death of Prof. Coffin is a loss to the world, and, in regard to him, we have to deplore that so much of his valuable life was expended in the drudgery of teaching, which ought to have been devolved upon inferior minds.

Dr. John W. Foster, the distinguished geologist and ethnologist, of Chicago, died June 29th. He was born at Petersham, Mass., March 4, 1815, and graduated at the Wesleyan University, of Middletown, Conn. He subsequently moved to Ohio, and connected himself with the geological survey of that State. In 1849 he entered upon a geological examination of the Northwest, in company with Messrs. Jackson and Whitney; and the observations they made are embraced in two volumes, entitled "Report on the Geology and Topography of the Lake Superior Land District" (1850–'52). Dr. Foster published an elaborate volume, "The Mississippi Valley," which gave an account of the physical geography, topography, botany, climate, geology, and mineral resources, of that vast and important region of the continent. He was President of the American Association for the Advancement of Science, at its meeting in Salem, in 1869, and has contributed numerous papers to the proceedings of that body and to the Chicago Academy of Sciences. He has been long engaged in the preparation of a work on the "Prehistoric Races of the United States," which was completed and printed, but not yet published, at the time of his death. It is an elegant volume, and a valuable contribution to the subject.

CORRESPONDENCE.

HYDROPHOBIA AN ACTUAL, NOT ALWAYS AN IMAGINARY DISEASE.

To the Editor of the Popular Science Monthly:

No doubt it is true that many persons have become ill, after being bitten by dogs, under a strong *apprehension* of hydrophobia. But, while scientific medical men ought to be, and mostly are, ready always to study "anew," that is, in view of all new facts, their oldest and most firmly-held opinions, yet some things have been clearly ascertained on this subject—not as matters of opinion, but as *facts:* First, that dogs (and, less often, some other animals) are subject to attacks of rabies, having a period of incubation, after being bitten, averaging, according to Youatt, five or six weeks. Also, every author of standing on the practice of medicine or surgery recognizes the fact that about one in ten of those human beings, of any and all ages, who are bitten by rabid dogs, will be, mostly within a month or six weeks, affected with symptoms entirely peculiar, ending in death in a few days, notwithstanding all the methods of treatment yet devised and used.

But the cases occurring in children are certainly the most convincing. Twenty years ago, I saw such a case, the whole history of which was known to me, in a boy eight years of age. My friend Dr. Lodge, of Montgomery County, Pennsylvania, informs me that, a few years since, he had charge of the case of a child of *five* years of age, some account of which occurs in Gross's standard work on surgery.

The importance of a right popular apprehension of the truth on this subject is considerable. Not only is it necessary that every clearly rabid animal should be killed promptly, and every suspected one fastened up and watched in security, but also that due *measures of prevention* should be resorted to at once, when any one is bitten. These measures (generally known) are, either the removal of the part, when practicable, or thorough *cauterization.* Should the idea become common that there *is no such disease* as hydrophobia in the human subject, as appears to be intimated in the article in your interesting "Miscellany," in The Popular Science Monthly for June, all such precautions are likely to be neglected, at the imminent risk of many lives, which, by means of such measures (if they be resorted to *immediately*), can be protected from this truly terrible malady.

Very respectfully,
Henry Hartshorne.

THE TRANSFUSION OF BLOOD.

To the Editor of the Popular Science Monthly:

The perusal of the article with the above title, in the April number of your magazine, brings to my mind two or three paragraphs from "Pepys's Diary" bearing on that subject, which may be interesting to your readers. Under date of November 21, 1667, we find: "With Creed to a Tavern, where Dean Wilkins and others: and good discourse; among the rest, of a man that is a little frantic (that hath been a kind of minister, Dr. Wilkins saying that he hath read for him in his church), that is poor and a debauched man, that the college have hired for 20*s.* to have some of the blood of a sheep let into his body; and it is to be done on Saturday next. They purpose to let in about twelve ounces; which, they compute, is what will be let in in a minute's time by a watch." November 30th, we have the sequel: "I was pleased to see the person who had his blood taken out. He speaks well, and did this day give the (Royal) Society a relation thereof in Latin, saying that he finds himself much better since, and as a new man; but he is cracked a little in his head, though he speaks very reasonably, and very well. He had but 20*s.* for his suffering it, and is to have the same again tried upon him; the first sound man that ever had it tried on him in England, and but one that we hear of in France." November 14, 1616, I find: "Dr. Croone told me that, at the meeting at

Gresham College to-night, there was a pretty experiment of the blood of one dog let out (till he died) into the body of another on one side, while all his own run out on the other side. The first died upon the place, and the other very well, and likely to do well. This did give occasion to many pretty wishes, as of the blood of a Quaker to be let into an archbishop [e. g., Laud?] and such like; but as Dr. Croone says, may, if it takes, be of mighty use to man's health, for the amending of bad blood by borrowing from a better body."

W. Woodbridge, M. D.

EDITOR'S TABLE.

SCIENCE IN EDUCATIONAL DISCIPLINE.

We note a very healthy curiosity on the part of many of our exchanges in regard to the progress of Mr. Spencer's discussion of Sociological Study. Now that he has considered the "Theological Bias," there is much solicitude expressed that he shall not forget the "Scientific Bias." Well, he has not forgotten it. We give his views in the present number of the Monthly, and commend them to the careful perusal of our readers. Mr. Spencer's treatment of the subject, however, has important bearings that he does not pursue. Although pointing out the influence of the study of various sciences in forming the mental habits necessary to deal with the single subject of Sociology, he in reality develops the disciplinary value of the sciences in their adaptation to the general work of education.

And the supreme question of education is undoubtedly that of mental discipline. Its primary object is to get the use of the tools of learning—the arts of reading, writing, and elementary computation. So much is indispensable for everybody; but, where education proceeds to its higher work, the next step is the application of the implements to the acquisition of knowledge. Here difficulties arise from its boundless extent. All subjects cannot be studied; whole ranges of them can never be even approached by any single mind; and, as what can be actually acquired is relatively so small, it was long ago seen that the main work of the school must be to form the mind and develop its capacities for effective action in subsequent life. An important truth was here recognized, but its bearing and exact value were far from well understood, and its undue influence led to bad results. For, although the principle is sound, that the chief purpose of education is to cultivate the mental capacities, yet this cannot be done except by means of studies selected for the purpose; and it was a grave mistake to lose sight of the value and adaptation of the knowledge to be gained, however comparatively small might be its amount. Yet such was the result. The staple studies of a liberal education had not been chosen with a view to their special mental influence, and were originally adopted for reasons of utility, because they were suited to the business wants of the professional classes. Yet their supremacy and permanence were defended on the ground of their incomparable merit for discipline. And, when modern studies began to press for increasing recognition in the higher schools, they were resisted on the principle that the acquisition of knowledge was not the object of academic study, but only mental training. The studies in use were defended for their superior claims in this respect, and the sciences were kept out of the schools, or but partially and grudgingly admitted, because they were said to be unsuited for the attainment of discipline. But this is one of the cases in which the truth turns out to be exactly the reverse of old and established opinion. The studies that have held their supremacy for ages, on the ground of their eminent suitableness for mental discipline, are at last losing their ascendency because of defects in this respect; and the studies which were long resisted because of their alleged unfitness to train the mind, are now coming into wide recognition as the best and indispensable means of attaining this end.

The educational advance here indicated is of the highest significance, for the old scholastic scheme which vaunted its perfect adaptation to the work of mental development was chiefly remarkable because it did not include a single branch of study which brought the mind into direct relations with Nature. It was, in fact, a scholastic curriculum in which Nature was entirely left out, and its discipline could hardly be other than partial and artificial. On the other hand, it now begins to be seen and acknowledged that the completest discipline of the human mind must come from the comprehensive and systematic study of Nature itself. This step is an immense gain to rational culture by putting an end to the old anomaly that the most valuable knowledge for application in life is antagonistic to that required for mental development. It is now perceived that "it would be utterly contrary to the beautiful economy of Nature if one kind of culture were needed for the gaining of information, and another kind were needed as a mental gymnastic. Everywhere throughout creation we find faculties developed through the performance of those functions which it is their office to perform; not through the performance of artificial exercises devised to fit them for these functions."

With the growing study of Nature, and the creation of those perfected forms of knowledge which we call science, the grave defects of the old methods of study have become more and more apparent, and are affirmed with emphasis by men of broad cultivation and the highest intellectual eminence. Mr. Mill shows that logic, the very science by which truth is investigated, was paralyzed for two centuries by the habit, prevailing in the universities, of regarding logical propositions as involving the relations of *ideas* instead of the relations of the *phenomena* of Nature. So long as logic and the connected branches of mental philosophy assumed that the investigation of truth consisted merely in contemplating and handling ideas, little was done in the way of discovery. Mind wrongly trained was barren of valuable results. It was only by the inversion of this procedure, and the adoption of the scientific method of study which brought the mind face to face with natural phenomena and gave it a new discipline, that the great and fruitful truths of modern knowledge have been attained. Dr. Whewell, late Master of Trinity College, in the Cambridge University, and a man of high scholarship, in his various works upon education, protested strongly against the deficiencies of the old system in the matter of discipline, and demanded the larger introduction of the sciences to repair their defects. He said: "The period appears now to have arrived when we may venture, or rather when we are bound to endeavor to include a new class of fundamental ideas in the elementary discipline of the human intellect. This is indispensable if we wish to educe the powers which we know that it possesses, and to enrich it with the wealth which lies within its reach."

In an able lecture by Prof. Helmholtz, just published in this country, "On the Relation of Natural Science to General Science," he considers the several branches of study as exercises for the intellect, and as supplementing each other in that respect. Admitting that a certain kind of discipline is obtained by the study of grammar and philology, he shows that it is radically defective, and requires scientific culture to correct it. He says: "In proportion as the range of science extends, its system and organization must be improved, and it must inevitably come about that individual students will find themselves compelled to go through a stricter course of training than grammar is in a position to supply. What strikes me in my own experience of students who pass from our classical schools to scientific and medical studies is, first, a certain laxity in the application of strictly universal laws. The grammatical rules, in which they have been exercised, are for the most part followed by long lists of exceptions; accordingly, they are not in the habit of relying implicitly on the certainty of a legitimate deduction from a strictly universal law. Secondly, I find them for the most part too much inclined to trust authority, even in cases where they might form an independent judgment."

Of such criticisms the literature of modern education is full, so that we may say that the traditional culture is now indicted before the world for breaking down at precisely that point in which it has claimed the greatest strength. That the old method of study disciplined the mind was nothing; the question is, What kind of discipline did it afford? All prolonged mental effort in any direction gives power and fixes habit, but the effect may be so narrowing and perverting that the discipline becomes an evil in proportion to its thoroughness. The need and value of scientific studies, as a correction of classical discipline, are now generally admitted; but, before any such correction can be intelligently or effectually made, it is necessary to know what sort of discipline the study of science confers. Science is a comprehensive term; it means various groups of sciences which exercise the intellect in widely different ways. A discipline may be scientific, and still be partial and deficient. We were, therefore, in need of a thorough analysis of the subject, and a statement of what the several sciences are competent to do in the training of the mental faculties. This want has now been supplied by Mr. Spencer.

Obviously the first thing here wanted is a classification of the sciences, and it is equally evident that such an application of it as is here contemplated would become a test of its validity. In a true classification, objects are grouped together which are most alike in characters, and only those sciences which are most similar will call forth like mental activities in their pursuit. Mr. Spencer divides the sciences into three groups: *Abstract* sciences; *Abstract-concrete* sciences; and *Concrete* sciences.

Abstract science is the science of pure relation, with no reference to the nature of the things related. The abstract sciences are logic and mathematics, and they deal with the abstract relations under which all phenomena are presented.

Mr. Spencer holds that space and time, the forms of phenomena, "are contrasted absolutely with the existences disclosed to us in space and time; and that the sciences which deal exclusively with space and time are separated by the profoundest of all distinctions from the sciences which deal with the existences that space and time contain. Space is the abstract of all relations of coexistence; time is the abstract of all relations of sequence. And, dealing, as they do, entirely with the relations of coexistence and sequence in their general or special forms, logic and mathematics form a class of the sciences more widely different from the rest than any of the rest can be from one another." These sciences are, therefore, better suited than any other to establish in the mind "unshakable beliefs in necessities of relation;" and Mr. Spencer points out the unequal values of logic and different branches of mathematics for this purpose.

As the first division takes into account only ideal relations, the second division takes up relations among realities. It includes concrete things, and gives rise to a division which Mr. Spencer, therefore, calls the abstract-concrete sciences. These are mechanics, physics, and chemistry. They deal with the laws of forces as manifested by matter, but when artificially separated from one another. Mechanics, physics, and chemistry have, for their object, to generalize the laws of relation of their several phenomena, when disentangled from those actual conditions of Nature in which they are mutually modified. For example: "In works on mechanics, the laws of motion are expressed without reference to friction and resistance of the medium. Not what motion ever really is, but what it would be, if retarding forces were absent, is asserted. If any retarding force is taken into account, then the effect of this retarding force is alone contemplated: neglecting the other retarding forces." This group of sciences introduces a new order of ideas which call out a different form of mental exercise. They deal with causation, and have great value in giving "distinctness and strength to the consciousness of cause and effect." By familiarizing the mind with numberless simple and separate cases of the action of forces, "they make it impossible to think of any effect as arising without a cause, or any cause as expended without an effect; and they make it impossible to think of an effect out of proportion to its cause, or a cause out of proportion to its effect."

Mr. Spencer's third division comprises what he terms the concrete sciences, or the real, as contrasted with the wholly or partially ideal sciences. They include astronomy, geology, biology, and psychology, which consider phenomena in their totalities or aggregates. These sciences, being far more complex than the preceding, and presenting their various phenomena in combination, are suited to cultivate the synthetical habit of mind, and to familiarize it with complex causation. Mr. Spencer shows that, while the concrete sciences cannot be made to give the mental discipline of the simpler groups, they are indispensable to exercise the mind upon the fundamental conceptions of continuity, complexity, and contingency in causation, and which are of the highest importance in the judgment of common affairs.

The authorities cited above, and which might have been greatly multiplied, establish the fact, beyond cavil, that there is a profound deficiency in the discipline of the current classical system of study; and they all agree that the introduction of science is alone competent to afford a remedy. Mr. Spencer has shown not only how comprehensive and varied is the discipline which the sciences are capable of yielding, but he has pointed out the radical insufficiency of limited portions of science for that complete mental training which it is the object of the higher education to give. In the interests of mental discipline, therefore, we are compelled to demand a reconstruction of the curriculum of "liberal culture," with not merely more of science in it, but with such an organized scheme of scientific studies as will accomplish the end desired.

LITERARY NOTICES.

Popular Lectures on Scientific Subjects. By H. Helmholtz, Professor of Physics in the University of Berlin. Translated by E. Atkinson, Ph. D., F. C. S., Professor of Experimental Science, Hoff College. With an Introduction by Prof. Tyndall. New York: D. Appleton & Co., 1873.

This is, in several respects, the most important scientific publication of the season, its interest being due not alone to its valuable contents, but quite as much to the form in which they have been put by their illustrious author. When the present MONTHLY was started, surprise was expressed in various quarters at the broad scope of its discussions, which it was said went far beyond the legitimate meaning of our title. Science being considered as a kind of tough and forbidding knowledge belonging to laboratories, observatories, and apothecaries' shops, popular science was regarded as the same kind of knowledge loosely stated in common language. At the outset we rejected this view as narrow and false, holding that science, instead of pertaining to certain things, consists in a method of knowing, which applies to all things that can be known, and that popular science must be equally comprehensive. Science itself being progressive, its great army of workers is constantly engaged in extending and correcting it by numberless processes of original investigation, while it is the office of popular science to bring its conclusions, applications, and results, into the sphere of common thought. Learned men long neglected the duty they owed to the public to clothe the result of their labors in authorized and acceptable forms for general use, and the consequence was that this work was done by incompetent hands, and degenerated into mere amusement and recreation; but, with the progress of liberal opinion, the diffusion of education, and increasing respect for the rights and welfare of the people, eminent men of science have turned their attention seriously to the task of embodying their ideas in popular form.

In his introduction to the present volume, Prof. Tyndall remarks: "One evening during my residence in Berlin, my friend Dr. Du Bois-Reymond put a pamphlet in my hands, remarking that it was the 'production of the first head in Europe since the death of Jacobi,' and that 'it ought to be translated into English.'" That "first head in Europe" was on the shoulders of Helmholtz, and the pamphlet was his celebrated essay on the "Interaction of the Natural Forces," which has been extensively circulated in this country, and is one of the most elegant and popular expositions of the doctrine of the "Conservation of Force" that has appeared in any language. The first complete work of Prof. Helmholtz in English is the volume now issued, consisting of popular lectures on scientific subjects. Speaking of these lectures in his preface, the author says: "If I may claim that they have any leading thought, it would be that I have endeavored to illustrate the essence and the import of natural laws and their relation to the mental activity of man. This seems to me the chief interest and the chief need in lectures before a public whose education has been mainly literary." It is gratifying to note that this statement of the chief aim of popular science entirely coincides with the view presented in the prospectus of THE POPULAR SCIENCE MONTHLY. It is not the illiterate that are to be addressed, but the classes that have received such cultivation as the prevailing educational system affords, while the development and illustration of natural laws in their bearing upon the higher nature and elements of man is the ultimate and most important end to be attained.

HERMANN LUDWIG FERDINAND HELMHOLTZ was born at Potsdam in 1821. He studied medicine, and was at first military physician and afterward assistant at the Astronomical Museum at Berlin in 1848. From 1849 to 1852 he was Professor of Physiology in the University of Königsberg. He became Professor of Physiology at the University of Bonn in 1855, and in 1858 accepted the physiological chair in the University of Heidelberg. He is now reëstablished in Berlin as professor in the university of that city. Prof. Helmholtz has attained a recognized preëminence in three great departments of knowledge—physiology, physics, and mathematics. He began with the study of physiology, but, finding that to be dependent upon physics, he proceeded to master the physical field. But here, finding again that physics depends upon mathematics, he pushed on to the conquest of this department of science. His great works are on "Physiological Optics" and "The Physiology of Audition," and, by his thorough acquaintance with physics and mathematics, he has greatly enriched and extended our knowledge of the science of these higher senses. Prof. Helmholtz's intellect is characterized by great breadth and synthetic grasp, which leads him to take large views, and treat the subjects he enters upon with comprehensiveness. The opening and closing papers of the present volume—the first, "On the Relation of Natural Science to Science in General," and the last, "On the Aim and Progress of Physical Science"—are admirable examples of this broad judicial treatment of the subjects discussed. His statement of the reactions of science and philosophy in Germany, and the influence of the German universities upon contemporary thought, in the first paper, is especially admirable. The volume also contains very able articles upon his special subjects of investigation—one "On the Physiological Causes of Harmony in Music," and another elaborate paper, in three parts, "On the Recent Progress of the Theory of Vision." There is also a very interesting lecture "On Goethe's Scientific Researches," and an elaborate discussion of glacial phenomena. Two papers are also given "On the Interaction and Conservation of Forces," a subject which Prof. Helmholtz has pursued independently, and which in these expositions is presented in its fundamental principles. Numerous illustrations enhance the instructiveness of the volume, which, though compactly written, is still remarkably clear in its explanations. Prof. Helmholtz is an eminent master of the art of statement, but, as his thoughts appear in a foreign language, the force and finish of the original composition are not to be looked for. Yet the several translations of this volume by Professors Eve, Ellis, Atkinson, Tyndall, and Drs. Flight and Pye-Smith, have been made with great care, so that the work is as attractive and readable in style as it is solid and instructive in its thought. We commend this book to all who are interested in the higher scientific problems of the age, as treated by one of its master-minds.

The Mineral Springs of the United States and Canada, with Analyses and Notes of the Prominent Spas of Europe, and a List of Sea-side Resorts. By George E. Walton, M. D. New York: D. Appleton & Co.

The author of this work seems at first to have been sorely perplexed as to whether there are or are not any medicinal virtues in mineral waters. The public is inclined to be credulous in regard to their remedial uses, and the medical profession is inclined to be skeptical about them. In point of fact, great numbers of people with divers ailments seek the mineral fountains of various localities, and use them very much at hap-hazard. At the same time he says that, while the American profession is inclined to be incredulous as to the medical services of these springs, eminent European physicians, such as Trousseau and Niemeyer, assign an important place to mineral waters in the treatment of many chronic diseases. In this unsatisfactory state of opinion, Dr. Walton entered systematically upon the inquiry as to the remedial uses of the mineral waters of the United States and Canada, and in the volume now printed he has endeavored to arrange all the known facts concerning them in such a manner that they shall be readily accessible, and serve to guide the reader in selecting such as shall be best adapted to his own wants: "For this purpose he has consulted the best European authors, their conclusions being drawn from hundreds of years of laborious investigation of the spas of Germany, France, Switzerland, and Italy. It has been interesting, in the course of this study, to note how closely the conclusions drawn by them, concerning the action of different classes of waters, agree with the observations made at springs in this country independent of any knowledge of foreign research. The portion relating to the springs of the United States is the result of a selection of credible evidence regarding them gained by correspondence and personal observation."

After some preliminary chapters on the nature, classification, and chemical constituents of mineral waters and their relations to various organs and diseases, Dr. Walton considers the springs of the country under the heads of "Saline Waters," "Sulphur Waters," "Chalybeate Waters," "Purgative Waters," "Calcic Waters," and "Thermal Waters," and the resources of the whole country are then given in respect to mineral waters having these various properties. Of all the localities in the United States or Canada, Saratoga is the most eminent for the extent and variety of its fountains. Dr. Walton gives the analysis of 15 of its springs, tabulating no less than 23 of their constituents held in solution; and of their general character he remarks:

"The principal constituents of these waters are chloride of sodium, the alkaline carbonates, and carbonic-acid gas, hence they may be termed *alkaline-saline* waters, of which the famed Seltzer Spring of Nassau is a typical example. In point of merit, the Saratoga waters equal, if they do not surpass, any of the kind in the world. The large amount of carbonic acid which they contain, and the favorable combination of ingredients, render them very easy of digestion, and, to most persons, exceedingly pleasant to the taste. Many wonder why it is that during the hot months of the year such numbers crowd to Saratoga, thinking it only a whim of fashion; but, aside from social attractions or amusements, there is a positive value in the water, and pleasure in drinking it, which will always attract multitudes to its fountains. These waters are especially adapted to cases of *dyspepsia;* those depending on high living and an engorged condition of the abdominal viscera are peculiarly subject to their beneficial influence. In *jaundice*, depending on catarrh of the biliary ducts, they are curative, and they would undoubtedly prove beneficial in cases of *gall-stones* with a tendency to their continual formation and passage. In *engorgement of the liver*, and all conditions of abdominal plethora, they are a valuable remedy."

Of these waters which "equal, if they do not surpass, any thing of the kind in the world," some have been long tried, and others are new discoveries. The celebrated Congress Spring has had a world-wide reputation from early in the century as one of the most valuable of mineral waters. The Hathorn Spring has only been known since 1868, but it furnishes an excellent water, which is coming rapidly into favor. Dr. Walton says: "In taste and general character, it resembles the Congress water, but is stronger." These waters "bottle well," that is, undergo no change by precipitation, and are thus available for transportation to multitudes who cannot visit the springs.

The Geyser Spring, which also yields a strong and excellent water, has lately attracted much attention. Our author says of it:

"This spring is one of the curiosities of Saratoga. It was discovered in February, 1870. During a dull season, the owners of a bolt-factory, in which it is located, concluded to bore for mineral water. They chose the cellar of the factory in which to operate. Having sunk a tube to the depth of 154 feet, the water burst forth in such a volume as to entirely inundate the premises. On attaching a tube of smaller calibre, the water was projected to the height of 22 feet, and continues spouting forth in an intermittent stream. It is highly charged with carbonic-acid gas, so much so that, when drawn from a faucet into a glass, it foams up like soda-water. It is also exceedingly rich in saline constituents."

Spencer's Descriptive Sociology.—Messrs. Williams & Norgate have just issued the prospectus of a unique and most elaborate work by Mr. Herbert Spencer, consisting to a large extent of the tabulated material which he has accumulated for his "Principles of Sociology." In preparation for the latter work, requiring as bases of induction large accumulations of data, fitly arranged for comparison, Mr. Herbert Spencer, some five years ago, commenced the collection and organization of facts presented by societies of different types, past and present. Though this classified compilation of materials was entered upon slowly to facilitate his own work, yet, after having brought the mode of classification to a satisfactory form, and after having had some of the tables filled up, the results appeared likely to be of such value that Mr. Spencer decided to have the undertaking executed with a view to publication: the facts collected and arranged for easy reference and convenient study of their relations, being so presented, apart from hypotheses, as to aid all students of Social Science in testing such conclusions as they have drawn and in drawing others. The work consists of three large divisions. Each comprises a set of tables exhibiting the facts as abstracted and classified, and a mass of quotations and abridged extracts, otherwise classified, on which the statements contained in the tables are based. The condensed statements, arranged after a uniform manner, give at one view, in each table or succession of tables, the phenomena of all orders which each society presents—constitute an account of its morphology, its physiology, and (if a society having a known history) its development. On the other hand, the collected extracts, serving as authorities for the statements in the tables, are (or, rather, will be, when the work is complete) classified primarily according to the kinds of phenomena to which they refer, and secondarily according to the societies exhibiting these phenomena; so that each kind of phenomenon, as it is displayed in all societies, may be separately studied with convenience. The three divisions, each thus constituted, comprehend three groups of societies: 1. *Uncivilized Societies;* 2. *Civilized Societies—Extinct or Decayed;* 3. *Civilized Societies—Recent or still Flourishing.* Several sample tables have been sent us, and as a specimen of the classifactory headings under which the immense array of facts are grouped, we shall give those belonging to Table IX. of Division I. ("Uncivilized Races"), the Sandwich-Islanders, one of the Malayo-Polynesian Races. First are given their Inorganic Environment (Climate, Surface); Organic Environment (Vegetal, Animal); Sociological Environment (adjacent tribes), Physical, Emotional, and Intellectual Characters. Then follow the tables, divided into Structural and Functional, each of which is subdivided into Operative and Regulative. The Structural Operative is again subdivided into Operative and Regulative; the Structural Regulative is subdivided into Political (*Civil* [Domestic (Marital, Filial), Public], *Military*), Ecclesiastical, and Ceremonial (*Mutilations*, *Funeral Rites*, *Laws of Intercourse*, *Habits*, *and Customs*). Under Functional, the Regulative is subdivided into Sentiments (*Æsthetic*, *Moral*), Ideas (*Superstitions*, *Knowledge*), and Language; the Operative into Processes (*Distribution*, *Exchange*, *Production*, *Arts*, *Rearing*, *etc.*), and Products (*Land-Works*, *Habitations*, etc., *Food*, *Clothing*, *Implements*, *Weapons*, *Æsthetic Products*). Under each final subdivision ample details are given. The value of such a work to all students of sociology, and of mankind generally, will be inestimable.—*Nature.*

Introduction to Chemical Physics, designed for the Use of Academies, High-Schools, and Colleges. By T. R. Pynchon, M. A., Professor of Chemistry and the Natural Sciences in Trinity College, Hartford. New York: D. Van Nostrand.

The principle of subdivision of labor, upon which our civilization rests, is nowhere more marked than in education. As knowledge extends, and greater thoroughness of study is demanded, science inevitably becomes specialized. A few years ago, two or three introductory chapters on the physics of the subject were prefixed to the treatises on chemistry: now an independent volume is required for the purpose. Miller's "Chemical Physics" is part of his encyclopædic work upon chemical science; but Prof. Pynchon's book is a complete treatise upon the subject, independently presented. The author considers the intimate bearings of heat, light, and electricity, upon the production of chemical phenomena, and his exposition is so full that it not only meets the wants of the higher educational institutions, but will prove equally useful as a guide for manufacturers and practical men. We are glad to see that this work is well appreciated abroad. The London *Mining Journal*, in a very commendatory review, epitomizes its contents as follows: "The history of chemistry is briefly sketched, and reference is made to the fundamental principles of the science, to the apparatus used, to the constitution of some of the most important chemical compounds, to the chemical agents—heat, light, and electricity—and why they are called imponderables, and to other similar elementary matters, a knowledge of which is required for the more profitable study of the succeeding chapters. The chapter on the first chemical agent—heat—is as complete a treatise on the subject as is found in the best college text-books devoted to the subject, and, although concise, the style is by no means uninteresting; the diffusion of heat-expansion, liquefaction, ebullition, evaporation, specific heat, sources of heat, nature of heat, are each treated of, the explanations being rendered particularly clear by the admirable illustrations by which they are accompanied. Light and electricity are dealt with in an equally complete and satisfactory manner, ample details being given with regard to the nature of light, its sources, reflection, refraction, the solar spectrum, spectrum analysis, the effect of light, and the relations of light and heat; while in the chapter upon electricity there are very full sections upon statistical and galvanic electricity, electro-magnetism, magneto-, thermo-, and animal electricity, and the relations which the several chemical agents bear to each other."

Fifth Annual Report on the Noxious, Beneficial and other Insects of the State of Missouri. By Charles V. Riley, State Entomologist. 1873.

That abundance of correct information about the habits of noxious insects should be diffused among farmers is a thing of capital importance. Many insect-pests, which in former times ravaged the fields and orchards with impunity, are now easily held in check, or exterminated, owing to the enlarged knowledge derived from the researches of scientific entomologists. For instance, after it is once known that the parent Hessian fly makes its first appearance in the latitude of Missouri, about the beginning of September, and usually disappears before the end of that month, the prudent farmer will preserve his grain from the attacks of that destroyer by deferring his planting till October. In like manner, the army worm may be defeated by burning up her eggs with the grass-stalks in which they are deposited. Or we may enlist in our service the natural enemies of the various insect-pests, such as birds, toads, snakes. But their greatest foes are "those of their own household," predaceous or cannibal and parasitic insects. The study of the habits of these insect allies and insect enemies of the husbandman is the occupation of the practical entomologist. The importance of entomological research is now more generally recognized than it was a few years ago, when Dr. Asa Fitch, of New York, was the only State entomologist in the Union. New York, it is true, no longer employs an entomologist, having very unwisely abolished the office two years ago. Other States, however, have instituted the office, and their example is likely to be imitated throughout the Union. The States at present employing entomologists are Massachusetts, Connecticut, Illinois, and Missouri, and Mr. Townsend Glover is attached to the National Department of Agriculture, in the same capacity.

Mr. Riley's very able report is in itself perfectly satisfactory evidence of the value of such studies.

We are pleased to see incorporated with the report a succinct treatise on entomology, intended to give the intelligent farmer an easy introduction to the science.

Eighteenth Annual Report of the Board of Directors of the St. Louis Public Schools, for the Year ending August 1, 1872. With Appendix; pp. 319.

This report contains a good deal of important matter that has a more than local value. Besides many instructive details relating to the management of the St. Louis schools, their accomplished superintendent, Mr. W. T. Harris, gives us his views on grading and classification in a system of schools, on the course of study for the public school best suited to modern requirements, and on the important subject of school discipline. On the practice of whipping in schools, he quotes from Superintendent Monteith, as follows: "The indiscriminate use of the whip in school is a practice which is to be condemned as barbarous, cruel, and wicked. It is a wonder that society is so indulgent toward that which, if applied to animals instead of children, would not be tolerated for a moment. I regret to say it, but it is true, that a 'society for the prevention of cruelty to children' could find work for humane hands in many Missouri schools. The case is aggravated when we consider, further, that about two-thirds of the whippings which school-children receive are inflicted for offences for which they are in no way responsible. The crimes they commit, upon which pedagogical vengeance is wreaked, when stripped of the color given to them by unmeaning and senseless rules, are simply the crimes of being a boy and being a girl. They are too often crimes which are incited by bad air, cold feet and shoulders, overwork, and long confinement. They are crimes which the parents of these same children are accustomed to excuse in themselves, when they sit in church, by the dulness or length of the sermon, or other circumstances that offend against Nature, and which they sometimes soothe with fennel or hartshorn, or by changing of position, and not seldom with sleep. When children know they are not really deserving of punishment, the effect of whipping is to deaden the moral sensibilities, diminish self-respect, and render young natures rude, reckless, and desperate."

The report proper closes with a summarized statement of the more important features of the St. Louis school system, which, both for the intelligent care with which it is directed, and the excellent results attained, is worthy of the consideration of educators generally.

Report on a Topographical Survey of the Adirondack Wilderness of New York. By Verplanck Colvin. Albany, 1873. The Argus Company, Printers.

This is an important contribution to the geography of the State of New York. All the maps of the Adirondack region hitherto published abound in inaccuracies, which are here, for the first time, authoritatively corrected. Even so prominent a landmark as Mount Marcy, the highest mountain of the State, is, in the usual maps, located miles distant from its true place. When a map of the Wilderness is constructed on the data of Mr. Colvin's survey, it will indicate a multitude of great streams, lakes, and mountain elevations, quite ignored by the map-makers. With regard to the future of the Wilderness, Mr. Colvin thinks that the whole water-shed of the Hudson, within the limits of the Adirondack region, should be preserved in its present condition, as a forest farm, and as a source of water-supply for the cities and great towns on the Hudson, from Troy to New York and Brooklyn.

MISCELLANY.

Fossil Monkeys.—With the title "On the Primitive Types of the Orders of Mammalia Educabilia," Prof. E. D. Cope recently read a very remarkable paper before the American Philosophical Society. The professor referred to a previous description, by himself, of certain fossil remains under the name *Anaptomorphus æmulus*, in which he pointed out similarities of the teeth and other parts to like parts in monkeys and man. He also quoted Prof. O. C. Marsh as saying that three fossil genera, previously described by himself, were all referable to the Quadrumana, or monkeys, saying that "they have the principal parts of the skeleton much as in some of the lemurs," the lowest of the monkey race. Some fossil remains, previously described by Prof. Cope, were referred to a genus *Tomitherium*, but with no suggestion as to the order to which they might belong. A reëxamination of this genus has caused it to be referred to the Quadrumana. A remarkable feature in the osteology of this genus is, the relationship shown also to the Coati (*Nasua*). "The first impression derived from the appearance of the lower jaw and dentition, and from the humerus, is that of an ally of the Coati (*Nasua*). The humerus, indeed, is almost a fac-simile of that of *Nasua*. . . A comparison with *Nasua* reveals no distant affinity." The fossil remains of these ancient monkeys were obtained in Eocene strata in the Bridger beds on Black's Fork, Wyoming, and already some seven species are described.

As an example of remarkable scientific prescience, as regards this monkey-cousinship of the *Nasua*, or Coati-Mondi, we give the following foot-note on page six of this interesting paper: "Dr. Lockwood, of Rutgers College, in a recent number of The Popular Science Monthly, expressed serious suspicions of the quadrumanous relationships of the Coati, little thinking at the time that the specimens to confirm his view were, at that moment, in the hands of palæontologists." It is also worthy of mention that Prof. Lockwood's singular induction was worked out of psychological considerations, he stating that the material basis was not at hand, although he insisted that such must exist. Results like the above cannot but give confidence in the processes of the science of comparative anatomy.

Light-Waves and Sound-Waves.—A curious instance of the analogies of light and sound is given in the *Medical Times*, from a German medical journal. Two brothers, named Nussbaumer, are said to receive visual impressions from sounds. When a certain note is struck upon the piano, the brothers at once have a sensation of a certain corresponding color, which is not, however, identical for both. Thus the note which produces in the one the impression of dark Prussian blue, produces in the other that of dark yellow. They do not, however, perceive all colors on occasion of hearing sounds. One of the brothers has sensations of yellow, brown, and violet, most frequently; while blue, yellow, and brown, are most frequent with the other. One of them never has the sensations of red, green, black, or white, awakened by musical notes, though on one occasion he says that, suddenly hearing a noise from the filing of a saw, he had the sensation of green. No doubt it is very difficult to be secure against deception in such a matter as this; but we may add that Prof. Brühl, of Vienna, after thorough investigation, is satisfied that there is no fraud.

Meteorological Observations in the Upper Atmosphere.—We take, from the Proceedings of the French Academy of Sciences, the following interesting account of meteorological observations made by M. G. Tissandier during a balloon-ascension in the month of February last: Six gentlemen accompanied M. Tissandier on his aërial voyage. The balloon, whose capacity was 2,000 cubic metres, was filled with illuminating gas. The ascent was made from the city of Paris, and the voyagers soon found themselves at an altitude of 1,200 metres, and enveloped in a dense layer of cloud. Having risen above this stratum of cloud, they entered a region where the sun's rays were intensely bright, and the heavens of a deep blue. For about three hours they sailed at an elevation of about 400 metres above the clouds. The shadow of the balloon, as it fell on this ocean of vapor, was very remarkable. At an elevation of 1,350 metres the shadow of the balloon itself had no halo, though one was visible around the shadow of the boat. At 1,700 metres the balloon's shadow was surrounded with rings of rainbow hues. Again, and at the same elevation, there appeared three distinct concentric halos. In all cases the violet was on the inner and the red on the outer side of the halos, but the blue and the orange colors were most clearly visible.

The temperature was very high, being 17.5° Cent., and the sun's rays so hot as to burn the face. The greatest altitude attained was 2,000 metres. As the balloonists descended through the cloud, a copper wire suspended from the boat gave strong indications of electricity. On reaching 1,200 metres, where the cloud was densest, the voyagers were unable to see the balloon above them, and were chilled by the cold, the thermometer showing 2° Cent. The copper wire gave out vivid sparks, and was quickly coated with ice-crystals, which glistened like diamonds. Similar crystals formed on the boat, and on the clothes and beards of the voyagers.

The descent was made at Montireau, distant 120 kilometres from Paris. Time, 3 hours and 45 minutes. M. Tissandier thinks that the dense opaline cloud through which he passed is made up of ice-crystals. The paper by Mohr, in THE POPULAR SCIENCE MONTHLY for May, shows that vapors can resist crystallization at a far lower temperature than 2° Cent.

Social Relations of Ants.—At the Congress of Swiss Naturalists, which assembled in August of last year at Friburg, Auguste Forel read an address upon the "Social Relations of Various Species of Ants." A nest is sometimes occupied by a community belonging to one species, sometimes by a community made up of two or more species, but all have the three classes of males, females, and workers. In a mixed community there will sometimes be found slaves—that is, workers of a different species made captive while still in the cocoon. When these emerge from their silken envelope, they become the friends and willing thralls of their captors, as though such were their natural destiny. A mixed community embraces all three sexes of the captor species, but only workers, or neuters, of the captive. The *Polyergus rufescens* and the *Formica sanguinea* both make slaves of the *Formica fusca*. The *Polyergus* is extremely indolent, but the *F. sanguinea* assists his slaves in their work.

There are certain species of ants which live by the labor of others without enslaving them. To this class belongs the *Anergates atratulus*, a species which have no workers, but which, both males and females alike, live in company with the workers of the *Tetramorium cæspitum*, and are tended by these latter, though the terms on which the association is formed are not known. The *Strongylognathus testaceus* also lives by the charity of the *Tetramorium*. But the author has discovered a species of *Strongylognathus* having true slaves.

Then there are mixed communities, where two species which usually live separately, lead a life in common; but this is a thing of very rare occurrence, and but little investigated. M. Forel has found ants' nests inhabited by the *Formica truncicola* and the *F. fusca*, by the *Tapinoma erraticum*, and the *Bothryomyrmex*, etc. On the other hand, he has also met with communities of the *F. sanguinea*, without slaves.

Inherited Traces of Surgical Operations.—In his fifth lecture on "Eggs," published by the *Tribune* of April 26th, Prof. Agassiz has the following on the transmission of individual peculiarities produced by surgical operations: "But, while the office of inheritance is to preserve typical features, its power to transmit individual peculiarities is also wonderful. My friend Dr. Brown-Séquard, who has made more experiments among animals than any man living, continuing them upon successive generations, and ascertaining what diseases may be transmitted, has stated facts to me which almost defy belief. These facts are unpublished. I will give a few of them. He has found that the disease of epilepsy can be induced in guinea-pigs by certain operations, and that this disease, being so introduced into the system, may be transmitted from generation to generation, and thus become hereditary. Where such operations have produced malformations of the skin, as is often the case, these also have been transmitted; or, where the paws have been affected by such operations, the peculiarity has been also transmitted. Malformation produced by these experiments as a disease during the life of a parent has been passed down to the offspring, and even habits arising from disease have been inherited in the same way. In one such case the peculiarity existed in the female; in another it was produced in the male. In the latter instance the male transmitted its own diseased condition to another generation through a healthy female. More than this, the female through whom these diseased descendants had been produced eventually became herself diseased in the same manner as the male. These facts have a fearful significance. With reference to the process, the subtle influence by which such results are produced, we must be silent for the present, since we cannot explain or understand it. All that we know is, that a material combination takes place which enables us to say that these individual peculiarities are sifted through the egg of the female and the spermatic particles of the male, and may reappear in their progeny."

Clay-eaters.—The Agmara Indians, inhabiting the shores of lake Titicaca, and the lofty plateau of the Andes, find the struggle for existence hard, at an altitude of more than 11,000 feet above the sea-level. Their principal articles of food are *quinoa*, a coarse grain resembling rice, and potatoes, of which tuber their country is the original home. The difficulty of boiling food at so great an altitude necessitates the previous maceration of all articles intended to be so cooked. The potato is, therefore, prepared for storing and use by exposing it to the frost; then it is placed in water, and stamped into a paste; all the soluble matter is washed out, and the starchy and farinaceous substance alone remains. This is called *chuno*, and it is made into a nutritious though insipid soup. The Agmaras use clay as an article of food, mixing it with *quinoa*. The clay they use is of a whitish color, and rather gritty. Careful analysis shows that it contains no organic matter, and therefore it must be used merely for the purpose of producing a satisfactory though delusive distention of the stomach.

The Faculty of Direction.—It will be remembered that, in the course of the discussion as to hereditary antipathy, a side question was introduced by Mr. Wallace, namely, the faculty possessed by certain animals whereby they are infallibly guided on their return homeward from distant places. Mr. Wallace thinks that this faculty is, in dogs at least, simply a very acute sense of smell. According to him, the dog "takes notes by the way" of the various odors he passes through, and finds his way back by taking the links of this chain in reversed order. But this explanation is open to very serious difficulties, and Mr. Darwin's simpler theory will appear far preferable.

Indeed, Mr. Wallace's theory seems hardly broad enough to account for more than a very inconsiderable fraction of the phenomena which it is proposed to explain. For dogs, cats, horses, and the like, it may be good enough, until a better theory is found. But what possible application could it have to such a case as the following, which is given by Mr. Edward W. Cox, on the high authority of Mr. Robert Fox, of Falmouth? "The fishermen of Falmouth," writes Mr. Cox, "catch their crabs off the Lizard Rocks, and they are brought into the harbor at Falmouth alive, and impounded in a box for sale, the shells being branded with marks by which every man knows his own fish. The place where the box is sunk is four miles from the entrance to the harbor, and that is above seven miles from the place where they are caught. One of these boxes was broken; the branded crabs escaped, and two or three days afterward they were caught again by the fishermen at the Lizard Rocks. They had been carried to Falmouth in a boat. To regain their home they had first to find their way to the mouth of the harbor, and, when there, how did they know whether to steer to the right or to the left, and to travel seven miles to their native rocks?"

It is unphilosophical to set up many different hypotheses, where one would answer. For this reason we are inclined to accept Mr Darwin's explanation of the phenomenon in question, rather than Mr. Wallace's. Mr. Darwin, it will be seen, aims at bringing all the phenomena under one general law, that of a Faculty of Direction, as it may be called. In confirmation of this hypothesis, the veteran naturalist quotes from Von Wrangell's account of his expedition to North Siberia, as to the "wonderful manner in which the natives kept a true course toward a particular spot, while passing for a considerable distance through hummocky ice, with incessant changes of direction, and with no guide in the heavens, or on the frozen sea." Even with the aid of a compass, an experienced surveyor in Von Wrangell's party failed to do what these savages easily effected. Mr. Darwin says the Siberians keep a sort of "dead reckoning" of their course, correcting their deviations partly by eyesight, partly also, perhaps, by a sense of muscular movement, as some men can, even with bandaged eyes, proceed for a short distance in a straight line, turn at right angles, or even back again. Some persons are "turned around," as we say, far more easily than others. Such persons would very easily lose their way, were they to attempt traversing an extensive forest, for instance. Mr. Darwin is inclined to think that some part of the brain is "specialized for the function of direction." If that is the case, it is very natural to suppose that this specialization may be more marked in beasts and savages than in civilized man, as the former have more constant need to exercise the faculty of direction than the latter. Mr. Darwin closes his communication on this subject by citing a case from Audubon, where the faculty of direction was egregiously at fault. The great ornithologist kept a pinioned wild-goose in confinement, and, when the time for migrating came, the bird escaped. Instead of proceeding due southward, as it should have done, the poor creature began its long journey on foot, travelling due northward, exactly the wrong direction.

Habits of the Porpoise.—The behavior of the porpoise in the Brighton (England) Aquarium has been studied with warm interest, by Mr. Henry Lee, F. L. S., who communicates to *Land and Water* an interesting account of his observations. Mr. Lee had previously enjoyed frequent opportunities of watching the porpoise at sea, whether from the bow of a steamer, or over the gunwale of a boat, but an uninterrupted, broadside view of all its movements was, for him, "a new, delightful, heart-stirring sight, and one often longed for." He observed that the tail, with its flat blade spread out horizontally, is the only propelling instrument possessed by the animal. Even when the creature is in rapid motion, the front fins hang straight down from the sides, and come into play only when it wishes to change its course, or to rise to the surface for the purpose of "blowing." For the latter object, both fins are raised toward an horizontal position, the action of the tail is stopped, and, with the impetus previously gained, the porpoise soars gently to the surface; there, the valve of the blow-hole opens, the breath escapes with a sound between a deep sigh and a quiet puff, and, without the slightest pause, the animal descends again.

The new porpoise at Brighton is four feet six inches in length. The tank in which it is kept is 102 feet long, so that the beast has a very fair opportunity to exhibit its paces. The whole of the first day it cantered incessantly from end to end of the tank, keeping usually at a depth of about three feet, and rising to blow every 15 or 20 seconds. It was very timid, shying at every movement among the spectators. At night, it showed a partiality for gas-light, restricting its movements to the end of the tank that was illuminated. The second day the creature was so tame that it would take food from the hand, dart off with it, and come back for more. When it catches a fish, it seizes it by the middle of the body, holds it there for a second, as if pressing its teeth into it, to make it flexible, and then swallows it at a gulp, without any effort to bolt it head-foremost. "The pretty creature," continues Mr. Lee, "has a nice, good-natured face, in which I fancy I can often read an expression of pleasure and animation, and is as full of fun and frolic as a Newfoundland pup, galloping along something like a dog after a stick, and tossing up its tail with a romping kick, as a skittish colt throws up its heels in play. If it lives, as I hope it will, it will probably become as tame and docile as a seal; for the porpoise is a very intelligent animal. It has a large brain, and acute sensibility."

Persistence of Cholera in Central Europe.—It would appear as if Asiatic cholera had become naturalized in Central Europe. For a few years past the disease has prevailed to a greater or less extent in the Austrian dominions, and the following notes, taken from the London *Times*, will show its movements since the beginning of the present year. At that time the disease existed in numerous localities of Galicia and Silesia, and in a few places in Moravia and Hungary. It was increasing in the city of Lemberg, and, though declining in Buda-Pesth, had not disappeared. During the month of January it invaded several new localities in Hungary, Silesia, Moravia, and Bohemia. During February the disease still continued in the districts just referred to, and lingered in Buda. The garrison of the latter city suffered from a serious outbreak during the last week of January and the first week of February.

The cessation of cholera on the Upper Nile is reported. Its ravages during the last half of 1872 extended over the entire region bounded east and west by the Red Sea and the Desert, and between Kassala, in the north, and Korosko, in the south. The questions of the internal sanitary condition of Persia, and the recent prevalence of plague and frequently-recurring epidemic of cholera in that country, are about to be submitted to a sanitary commission appointed by the European powers, Persia, and Turkey. It is admitted that, so long as the sanitary condition of Persia remains what it is, Europe will continue to be visited by this scourge. The recent outbreak of plague in the Shah's dominions seriously endangered the Ottoman provinces of Asia, and it is at the instance of the Porte that the European powers now demand that the internal sanitary state of Persia be improved. This is a matter that very nearly concerns us, even on this side of the Atlantic, and it is to be hoped that the commission will perform its work thoroughly. Religious scruples and antiquated customs will make resistance, as a matter of course; but the civilized world cannot afford to see its population decimated, simply because unwashed devotees will insist on making their unwholesome pilgrimages. In a country where only a few years ago the government put a stop to corpse-caravans, the commission is sure to have enough to do. It was only in 1867 that a stop was put to the popular custom of transporting, on the backs of camels and mules, one or two hundred putrefying corpses at a time to certain holy places, often distant thirty or forty days' travel.

Sponges.—Naturalists are now generally agreed in classing the sponge with animals, but place it in the very lowest rank of the *Protozoa*, abutting on the vegetable kingdom. Like a plant, the sponge grows on rocks or other substances in water, being often found attached to the shells of living crustaceans. It consists of a gelatinous substance called *sarcode*, and of a framework made up of horny, elastic fibres (*keratose*), or of calcareous or siliceous spicules. The keratose is the sponge of commerce, and its value depends upon the elasticity and compressibility of its fibres.

The sarcode is sometimes represented to be an amorphous mass of glairy substance, but accurate observation with the microscope shows, according to Huxley, that it is constituted as follows: There is, first, an external layer, continuous, and made up of an aggregation of organisms with nuclei, and much resembling amœbæ. This stratum is separated from another of identical structure by a chamber filled with water. The outermost layer has a multitude of pores, through which the supply of food and oxygen enters. The floor of the lower and thicker layer has a number of orifices opening into tubes which widen out into globular caverns a little below the surface. The sides of these globules are studded with amœba-like organisms, each having a cilium, or appendage resembling an eyelash, which is constantly vibrating, and so establishing a current in a direction downward into canals which open into great, funnel-like, or crater-like orifices. These great orifices are the *exhalant* apertures, the pores *inhalant* apertures. The food and oxygen in the stream of water is appropriated by the sponge-organisms individually as it flows by.

When placed under the microscope, the living sponge is a wonderful sight. Dr. R. E. Grant, who was the first to witness it, having put a small branch of living sponge, with some sea-water, into a watch-glass, saw a "living fountain vomiting forth from a circular cavity an impetuous torrent of liquid matter, and hurling along, in rapid succession, opaque masses, which it strewed everywhere around." Here is a circulation of water answering the same purpose as that of blood in other animals. The sponge takes in food and oxygen through its minute pores, and voids the waste matter through the oscula, or larger orifices. In the *Spongia fluviatilis*, or fresh-water sponge, the pores are not permanent, but they appear and disappear without leaving a trace behind, as in the case of the amœbæ.

The spiculæ of the siliceous sponges assume sundry shapes, being sometimes straight, like needles; again headed and pointed like pins, or furnished with grapnel-like hooks at their ends, etc. Perhaps the most curious of all the sponges is the "glass-rope" (*Hyalonema*), which has the appearance of a rope of twisted glass fibres, with a fibrous sponge attached to one end. Another very interesting form of sponge is the *Euplectella speciosa*, or Venus's flower-basket, which grows in the shape of a cornucopia, and is composed of fine glossy threads of silica.

The best sponges for toilet use come from the Ægean, and are found in about eight fathoms of water. They are gathered by divers. A coarse quality of sponge is found on the coasts of Florida and the West Indies. These are gathered with long-hafted forks. To remove the sarcode, the sponge is buried for some days in the sand, until the animal matter rots, and then the horny keratose is soaked and washed.

Jute-Paper.—One day's issue of the Dundee (Scotland) *Advertiser* was recently printed on paper made of jute. The material is said to be of good, firm quality, though thin and transparent, and of a yellowish tinge. The chief objection hitherto urged against jute-paper is its dark color; and, if, as appears probable, this can be obviated, there is no doubt that jute-paper will quickly supersede that made from rags, except for the best qualities. The jute employed in this instance is old bagging, which commands but a low price. As an encouragement to inventors, the proprietors of the *Advertiser* offer a premium of £50 for the best ream of paper made entirely from jute, of the size and weight of the paper on which the journal is usually printed, the maker undertaking to supply 50 tons at a price not exceeding 4½*d.* per lb.; and a premium of £100 for the best ream of paper made entirely from jute, in size and weight as above, the maker supplying 100 tons at 4*d.* per lb. Old jute bagging may be bought in any quantity, in Dundee, at £9 10*s.* per ton.

Facts for Spencer.—Some striking illustrations of governmental negligence are given in the *Lancet*, in an article on "Army Medical Services." The writer states that in the armies of the first French Empire there was one surgeon to each 130 men. The French troops sent to Algeria in 1830 had only six surgeons to each 1,000 men. In the Crimean War the proportion was less than one (0.72) per 1,000. Throughout the war, the average number of patients under the care of each surgeon was 300. In the Italian War affairs were about as bad—less than one surgeon per 1,000 men. After Magenta, each surgeon had 175 wounded men, and after Solferino 500 under his charge. If he devoted 2½ minutes to each case, every moment of 24 hours would be taken up. The writer refers in terms of commendation to the medical and sanitary service of the United States during the late War of Secession. During the war between Austria and Prussia, 26,000 wounded of both armies were left, after the battle of Königgratz, totally without medical assistance, and unsupplied with food or water. The French army in the late war with Prussia had only two medical officers per 1,000 men, but 4½ veterinary surgeons per 1,000 horses!

A Singular Race.—A French traveller, M. Duveyrier, describes, in "Ocean Highways," a curious race, the Imôhagh (called in our maps Tauricks or Tuâregs), who dwell in the heart of the Sahara. They are pure Berbers, with white skin, but their uncleanly habits give them the appearance of blacks. The men alone wear a thick black veil over the face, while the women dispense with that covering. A man would consider himself dishonored were he to expose his face, and he takes precaution against any involuntary breach of decorum, by wearing his veil at all times, whether sleeping, walking, fighting, riding, and even speaking to his father. As a general rule, the Imôhagh despise fire-arms, as fit only for cowards, "but they fear them extremely" remarks M. Duveyrier.

They treat their women with great respect. No Imôhagh woman would consent to her husband indulging in plurality of wives; and, what is perhaps more singular still, the women alone know any thing of the art of writing. In political affairs the weaker sex exercise a powerful influence; and, when a chief dies, the supreme authority descends to the eldest son of his eldest sister.

Reproduction of Eyes in Crawfish.—That the crawfish has the power of reproducing an eye which it may happen to lose is a fact quite familiar to naturalists, but we are indebted to M. S. Chantran, of the French Academy of Sciences, for the discovery that this power of reproduction varies according to the animal's age. In a recent number of the *Comptes Rendus*, M. Chantran gives the results of his observations on this subject, from which it appears that a crawfish one year old quickly and effectually repairs such injuries, while in animals two or more years old reproduction is uncertain in its operation, and never perfect. His first experiment was with a number of one-year-old animals. In October, 1871, after the close of their moulting season, he clipped off their eyes. Moulting commenced in May of the year following, and in September, after four months, the eyes were perfectly reproduced.

The next experiment was with animals two years old. These he deprived of their eyes, either immediately before moulting set in, or in the interval between two moults. The results in these cases were various. In some of the animals, after three or four months, the eyes were reproduced, but then the pupils were so disfigured as to leave it doubtful whether they could serve for the purpose of vision; in others, one pupil was considerably smaller than the other.

Finally, in the case of full-grown animals, which moult less frequently—the females but once a year, and the males twice —the author's results did not show any reproduction of the eye, but only the growth of *buds* marked with a black point, and, in one case, of opaque bifid buds in place of eyes. The author promises at an early day to communicate to the Academy his observations on certain concretions formed in the stomach of the crawfish, and called *crab's eyes* in old pharmacopœias.

The Amarantus Blitum.—M. Boutin's observations on the *Amarantus blitum*, briefly alluded to in a late number of the Monthly, are so important as to call for a fuller statement. The amarantus belongs to the order *Amarantaceæ*, which contains nearly 300 known species. Some of these are familiar annuals in flower-gardens. The *Amarantus blitum* is a weed growing abundantly in many parts of Europe, and has never hitherto been supposed to possess any properties of economical value. Boutin's attention was first called to this plant on seeing it employed in scouring brass utensils. He supposed that it must contain some free acid or some acid salt. He found with surprise that it was completely neutral, and contained only nitrate of potash (saltpetre). To determine the proportion in which this salt enters into the constitution of the amarantus, he reduced to ashes 100 grammes (between 3 and 4 ounces) of the dried plant. The 16 grammes of ashes were treated with warm distilled water, and the whole then thrown into a filter. Having washed well the insoluble portion which remained in the filter, the author evaporated the filtered liquid, and so obtained a residue of carbonate of potash, 8 grammes. This weight of the carbonate is the equivalent of 11.68 grammes of the nitrate of potash, or saltpetre. The insoluble portion remaining in the filter would, on desiccation, give a weight equal to that of the carbonate obtained, or 8 grammes, to make up the original 16 grammes of ash. This insoluble portion consisted of lime, oxides of iron, alumina, and silica, with a small amount of phosphate of potash.

The author remarks upon the importance of this plant as a manure. It is superior to guano. And, if from any cause the supply of nitre for the manufacture of gunpowder were cut off, this plant could readily furnish it in any quantity. The question now arises, whence does the amarantus directly derive its nitrogen—from the soil or from the atmosphere? In the spring of 1872 the author had a plot of ground broken up with the spade, to a depth of about 8 inches, and kept free from all vegetal growth during the entire summer. This ground was in a condition to receive all the nitric acid and ammonia produced in the atmosphere by electricity. Yet, on a very careful analysis, no appreciable quantity of the nitrate could be found. On the other hand, the amarantus growing in the immediate vicinity yielded the usual amount—10 to 12 per cent. of the dried plant. Hence the author concludes that plants derive their nitrogen directly from the atmosphere.

Discovery of Ancient Egyptian Mines.—Some of the iron-mines anciently worked by the Egyptians have recently been discovered anew by English explorers, and search is to be instituted for other ancient mines of silver, gold, and iron. As the processes followed in ancient times for the reduction of ores were very defective, it is expected that, in the *débris* accumulated in the neighborhood of the mines, an amount of the useful and precious metals will be found sufficient to make the working it over again profitable. At a recent meeting of the British Society of Antiquaries, mention was made of the discovery, in the neighborhood of Mount Sinai, of the turquoise-mines of the ancient Egyptians. The discoverer, an Englishman, whose name is not given, observed in the water-courses of that region, which in summer are dry, peculiar blue stones which he soon ascertained to be turquoises. This circumstance led to further research. We are now informed that, "aided by the friendly tribes he has taken into his pay, he has discovered the old turquoise-mines of the ancient Egyptians, the rocks that they worked for the stones, the very tools they used, and their polishing and grinding places." The fortunate discoverer has already sent to England some of the finest turquoises ever seen.

While searching for the turquoise-mines, this same explorer discovered the ancient lines of fortification surrounding the works, and came upon the remains of vast iron-works, which must have employed many thousands of hands. Slag taken from the refuse-heaps around these works contains as much as 53 per cent. of iron. The whole surrounding district is well worthy of being thoroughly explored by the antiquary, as it contains many hieroglyphic inscriptions which would doubtless throw much light upon the early history of metallurgy.

The Sack-Tree.—A notable tree is the *Antiaris saccidora*, or sack-tree, of Western India, the inner bark of which forms a very good material for sacking, and also for cordage. It often attains a height of 100 feet, with a diameter of six. The native method of making sacks of this material is very simple. Usually a tree about one foot in diameter is chosen, and from this a section of the length desired for the sack is cut. This log is steeped for some time in water, in order to soften the bark, and is then beaten all round with clubs. In this way the outer bark is removed, and the inner detached from the wood and rendered soft and pliable. Next it is folded over on itself at one end, after the manner of skinning a squirrel, and so turned inside out. All that is now required to complete the sack is, that one of the ends be sewed up, which is readily done. But a sack may be made without stitch or seam. This is done by arresting the process of *skinning* some two or three inches above the farther end of the log, and then sawing off the latter at that point. The sack has then a solid wooden bottom.

These sacks are extensively used in Western India and Ceylon, and serve their purpose very well. The same material is sometimes employed in the manufacture of clothing, and for paper-making. To prepare it for the former purpose, the bark is stripped off in pieces, which are then thoroughly soaked and beaten out till the texture becomes white and rough like fur. It is then cut according to the required shapes, and stitched together.

Substitute for Quinine. — The employment of carbazotate of ammonia (ammonia combined with carbazotic, picric, or trinitrophenic acid) has been suggested as a substitute for sulphate of quinine, and Dr. Beaumetz, of the Société Thérapeutique de Paris, gives the following as the result of his employment of this salt: Case 1, quotidian ague. Daily dose one to two centigrammes in pills. Recovery in 4 days. Case 2, quotidian ague. Complete recovery in 5 days—five pills used. Here sulphate of quinine had been used without effect. Case 3, tertian. Recovery after 8 days—two pills a day. Case 4, quotidian. Recovery after 8 days. Case 5, facial neuralgia. Speedy recovery. Case 6, tertian, recovery in 2 days. Dose about one grain (6 centigrammes). Sulphate of quinine had been given for 17 days, without effect. Dr. Beaumetz hence draws these conclusions: the carbazotate is very efficacious in intermittent fever, and the paroxysms may be suppressed by the use of 2 to 4 centigrammes ($\frac{1}{3}$ to $\frac{2}{3}$ grain) daily. In these doses the drug appears to be innocuous. Its physiological action resembles that of sulphate of quinine.

NOTES.

There is in Cayenne a fly, called the *Lucilia hominivorax* (man-eater), which commits great havoc among the convicts sent out to that colony by the French Government. M. Charles Coquerel says that this fly lays its eggs in the mouth or nostrils of a sleeping convict, especially a drunken one, and that the offspring in their larval state usually bring about the death of their victim.

The following curious statement comes to us on reliable authority: A vicious horse (gelding) that had the singular habit of striking violently with his fore-feet, especially when being shod, was for several years worked with a mare that during the time bore a colt. This colt, when quite young, developed the habit peculiar to its mother's mate, becoming violent when any attempt was made to handle its fore-limbs. The habit increased with the colt's age, and, on being shod the first time, its manner of striking was observed to be precisely like that of the horse. The mother of the colt was unusually kind and gentle.

A statement of some interest occurs in *Scribner's Monthly*, showing the increasing demand, among the reading-classes of New York, for works of a scientific character. The writer compares the number of books called for at the Astor Library, in the literary and scientific departments respectively, during the three years 1865, 1871, and 1872. In the first of these years, 18,896 scientific works were called for by readers, and 26,070 literary; in the second, 33,428 scientific, 58,595 literary; in the third, 55,660 scientific, 55,657 literary.

In his late work on the "Physiology of Circulation," Dr. Pettigrew gives the following as the rate of the heart-beats in man at different periods of life: In the human fœtus the heart beats 140 times per minute; at birth, 130; second year after birth, 100; third year, 90; fourteenth year, 80; middle age, 70; old age, 60, or even less. The variation in the frequency of the beat of the heart in the lower animals is still more remarkable.

From the United States statistics, it appears that the percentage of insanity, idiocy, etc., is greater among the white population of this country than among the black. Thus, among the whites, one in 2,253 is deaf and dumb; among the colored race (blacks and mulattoes), only one in 3,780; insane whites, one in 943; colored, one in 2,750; idiotic whites, one in 1,575; colored, one in 1,530. The statistics of blindness, however, are more unfavorable for the colored race: blind whites, one in 2,000; colored, one in 1,469. The insane females, both white and black, outnumber the insane males, 19,202 against 18,179; but the male idiots are greatly in excess of the female—14,476 against 10,046.

There is found in Bombay a minute variety of ants which surround their nests with a series of concentric circular walls an inch or an inch and a half high, and about the same distance apart, the innermost wall being the highest. The object of these walls or fortifications is not yet known.

During a botanical exploration of the region around the river Coanza, in Lower Guinea, Dr. Welwitsch's party found their supply of provisions exhausted. The men accordingly went in search of food, with senses quickened by hunger. They were so fortunate as to discover an enormous mushroom, as large as an umbrella, which made soup enough to satisfy the hunger of 20 men. This specimen was the first of the species seen by Welwitsch, but subsequently he often met with it, and learned that these great mushrooms are brought to market at Pungo Adongo by the natives, and there sold at from one to three pence each, according to size.

By act of Parliament of the year 1843, mechanics' institutes, literary and scientific associations, and the like, were exempted from local taxation in England. The Government now proposes to do away with the exemption, thus imposing a tax on knowledge. If the measure succeeds, many societies must close their doors, and the work of popular education will receive a serious check.

A "memorial volume," to commemorate the services rendered to science by the late Prof. Liebig, is to be published by the Royal Bavarian Academy of Sciences, of which body he was president. The volume will contain an obituary notice of the deceased, and three separate dissertations upon the services rendered by him to physiology, agriculture, and theoretical chemistry, to be written by Profs. Bischof, Vogel, and Erlemeier.

The amount of tobacco paying duty and cleared for consumption in Great Britain steadily increases. Thus in 1841 it averaged 13¾ oz. per capita; in 1851, 16¼ oz.; in 1861, 19½ oz.; and in 1871, 21½ oz.

The average number of persons per house, in various cities of the United States, is as follows: New York, 14.72; Cincinnati, 8.81; Brooklyn, 8.64; Boston, 8.46; Jersey City, 8.37; Hartford has 5.56; Rochester, 5.36; and Toledo, the lowest, 5.20. The densest population is that of the Fourth Ward, New York, where there are 24.61 persons to each dwelling.

The Russian Government is about to construct a railroad from Nijni-Novgorod on the Volga, to the Japan Sea, about 4,200 miles. This line, in conjunction with that from Nijni-Novgorod to St. Petersburg, will connect the Baltic Sea with the Pacific. The road will run east in latitude 56°, 850 miles to Tobolsk, crossing the Ural Mountains. From Tobolsk it will take a south-east course 1,500 miles to Irkutsk, on Lake Baikal (latitude 53°). The remainder of the route is not yet determined on, but it is expected that work will be commenced on the western end during the present year.

Lake Neahtawanta, near the Oswego Falls, is a noted fishing-ground, containing abundance of pickerel, pike, perch, bass, and indeed nearly all the fresh-water fish. But a sort of epizooty recently broke out among the pickerel, which threatens to utterly destroy all the fish of that species contained in the lake; indeed, it is believed that they are already destroyed. The other fish in the lake are not affected by the disorder.

Dr. Lyon Playfair has no very high opinion of the value of English university education. He said recently in Parliament that "a Scotch university teaches a man how to make a thousand a year, an English university how to spend it."

Mr. Benjamin Smith, of London, has sailed for the north-pole in the yacht Diana. Mr. Smith expects to join his supply-yacht, the Samson, at Cobbe's Bay, on the north-west of Spitzbergen, latitude 80°. From that point he will push as far northward as the ice will permit. He purposes returning home in one year at the farthest.

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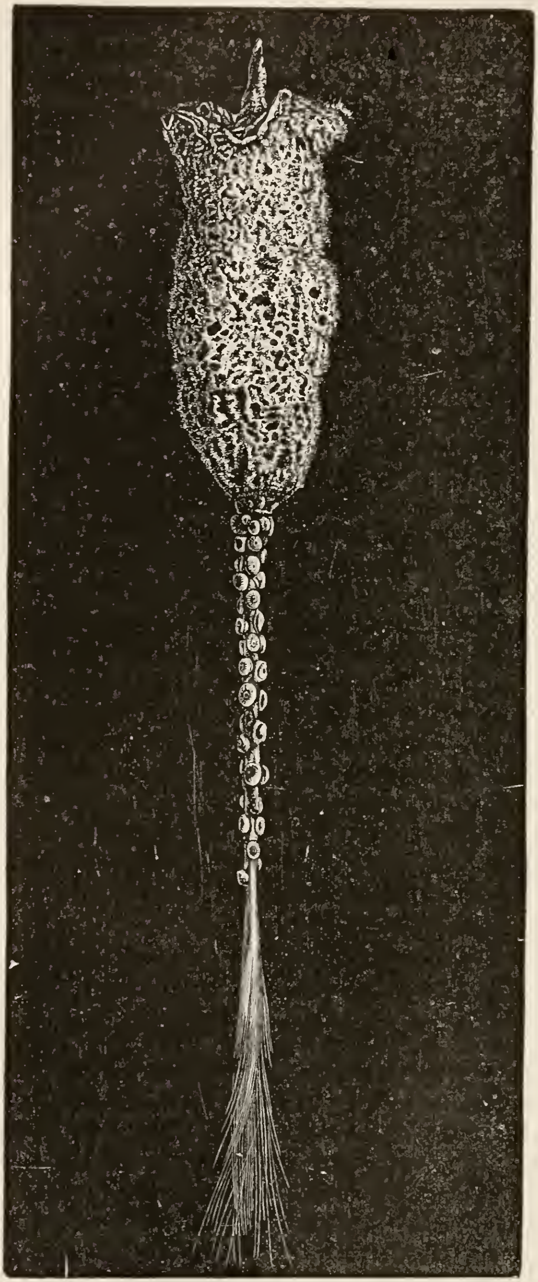
THE GLASS-SPONGES.

BY REV. SAMUEL LOCKWOOD, PH. D.

MY attention was absorbed in the study of an object contained in a vessel of sea-water that stood upon the table. It was clad in a suit of vermilion velvet, which, with its branching form, made it not unlike the precious red coral of the Mediterranean. I had been trying with a lens to see the water-current leaving the exhaling orifice. Observation was arrested; for it had become evident that the heated condition of the water had smitten my little beauty with death. "Please tell me the name of that pretty plant," said a visitor. The reply was: "Sir, that is not a vegetable, but an animal structure. It is a dying sponge." The question has been long mooted, whether the sponge was an animal or a plant. In Japan it is called "sea-cotton;" and, until recently, this vegetable view was held even in scientific circles. Prof. H. James Clark, the learned author of "Mind in Nature," so long ago as 1857, unfolded with remarkable clearness the peculiar cell-structure of the sponge. Last year an English naturalist, H. J. Carter, fed a living calcareous sponge with indigo, then made out the cells with the coloring-matter contained. He declares himself to have fully confirmed what Prof. Clark had written. Both agree in regarding the sponges as a group in that division of the animal kingdom known as the Protozoa, and nearly allied by their uniciliated cells to the Flagellate Infusoria. These infusoria are very minute animalcules, which have certain cilia, or hair-like appendages, by which, with a lashing motion, they propel themselves through the water. Each sponge-cell has one lash, or *cilium*. Indeed, this cell has a sort of individuality of its own, and yet millions of these almost infinitesimal one-celled beings are united to make up the one zoological individual known as a sponge. But, as the sponge-mass is fixed, and cannot travel, why should its cells be ciliated at all? Have they any whipping to do?

Fig. 1.



Hyalonema Lusitanicum, the Glass-rope Sponge. Half the natural size. The brush-like threads at the bottom form a twisted rope terminating in the teat-like projection at the top, where it is covered with fine sponge. This coil is the Glass-Rope. The sheath, or incrustation of little starry warts, is the work of a polyp, known as the *Palythoa fatua*. The conical head is a mass of sponge once called *Carteria*.

In a word, what is the function of this lash in each of these cells, which, combined, and taken with the skeleton, constitute a sponge? Let us try to see. If we take a morsel of a toilet-sponge, and put it under a microscope of moderate power, we find that it is made up of a mass of complicated net-work. There is more or less regularity in the meshes; and these are found of various patterns in the different species. This heap or mass of net-work, commonly called a sponge, is really the skeleton of the sponge. When living it is covered with, or literally embedded in, a glairy, gelatinous, or albuminous substance. But this is so unlike ordinary animal tissue—for it seems, really, tissueless—that it has received the technical name *sarcode.* This sarcode fills the meshes above mentioned; and is held in place by innumerable tiny spicules, mixed in, so to speak, like the hair in the mortar of the plasterer. So little consistency has this sarcode, or sponge-flesh, that but for this natural felting it would dissolve and flow away. Now, take an ordinary sponge into the hand. We observe several large apertures, at or toward the top. These are called the *oscula.* They are the exhalant vents of the entire system. At these openings is expelled, with some force, the water that has been taken into the living mass, and deprived of its nourishment. But how is the water brought in through that glairy sarcode? Besides the oscula, which are few, and readily seen, even in the skeleton, there are innumerable tiny inlets known as *pores.* These are not visible in the skeleton, as they really belong to the sponge-flesh. These pores open into the meshes, and enter directly certain little cavities, or chambers, that stand connected with circuitous passages, which finally lead to the large outlets, or oscula. The pores are very small, and yet, compared with the cells, are very large. The little chamber into which the pore opens has its walls built up with these uniciliated cells. Now, if we could only peep into the privacy of that chamber, with its walls of living stones, without making any disturbance, we should find every cell lashing its cilium with great vigor, and all in such harmony of accord, that it would seem like

> "Beating time, time, time,
> In a sort of Runic rhyme."

The beating of each lash is doubtless downward, that is, inward; the effect of which is, a *vacuum* above, into which the water presses through the external pore. A second result of this downward beating of the cilia from a myriad of cells is, the impulsion of the passing water through the ramifications leading to the oscula. Thus the running of the waters is the sponge's ancient "Runic rhyme." Every sponge, then, has a very complete aquiferous system: its conduits at, the entrance of and along which the busy one-lashed cells occupy themselves forcing the water along; and the oscula, which may be likened to the outlets of sewers. During this circulation of the fluid through the living mass, the sarcode obtains its nourishment, and the skeleton its growth by a sort of absorption, or what is known to the physiologist as endosmotic action of the cells. We have then mentioned above three clearly specialized functions, as represented respectively by the inhalant pores, the exhalant oscula, and the uniciliated cells. And it is certainly a matter of prime importance that each cell should have this single lash. In fact, it raises it to the rank of a pacha with one tail, in a community where all are pachas of this dignity, and each one a commissioner of the water department, and a commissary of subsistence. "Both the oscula and pores can be closed at the will of the animal; but the oscula are permanent apertures; whereas, the pores are not constant, but can be formed afresh whenever and wherever required."

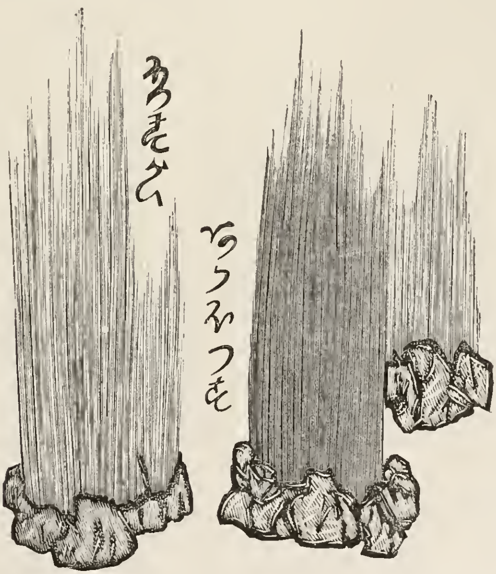
The sponges are the active eliminators of the salts of the ocean. In a large laboratory certain substances are kept in solution, so as to be ready to the chemist's hands. Nature's grand laboratory is the sea. There her little economic chemists are ceaselessly busy extracting, and putting into solid forms, the various mineral substances held in solution. Thus the coral polyps eliminate the carbonate of lime with which to build their beautiful structures. And the Alcyonarian polyp in this way builds up the delicate sea-fan, with its skeleton of keratose, or horn-like substance. And so is it with the sponges. They, too, are elaborators of the mineral treasures of the sea. Hence it has been attempted to group them upon considerations of their special building propensities. In this way the toilet-sponges, and, in general, those of commerce, which all affect horn, or keratose, in the structure of their skeletons, would be grouped together as the Keratosa; while those which choose lime would be called Calcarea; and those which build up with silex would be known as the Silicea. We have mentioned these groups in their order of rank. The highest is the vitreous, or glass-sponge, with which we are directly concerned.

In the recent deep-sea dredging, so charmingly described in Dr. Wyville Thompson's new book, "The Depths of the Sea," an account is given of the obtaining in British waters, at the depth of 30,000 feet (!), specimens of the Hyalonema, the famous Glass-Rope Sponge. It had been previously obtained from the coasts of Portugal, when the news astonished naturalists, as previously it had only been known as coming from Japan. It is, indeed, a wonderful object. We once saw a specimen in the cabinet of a learned institution. The professor pronounced it a coil of Japanese spun glass. "No," said another *savant*, "it is a plant." And at that time both were excusable, for even Ehrenberg had looked upon it as "an artificial product of Japanese industry." That is to say, the great microscopist regarded the object as an ingenious imposition, consisting of natural products artfully put together. Let the reader carefully inspect the cut of Hyalonema, Fig. 1, which we have taken from Dr. Thompson's book, and then let us attempt a description.

Suppose we should take a skein of smooth, compactly-spun, glossy white silk, about twenty-four inches in length, and, cutting the ends off evenly at one extremity, should give it a loose twist along the entire length, except some six inches at the bottom, which we leave, so to speak, frayed, or shaken out. Then around the other end of this silken cord or coil we affix a cup-like tuft of buff-colored zephyr worsted-work, having the end of the skein projecting a little higher than the rim, and covered with the same material. Now, from just below the base of the cup-like tuft, let us encase the white coil tightly down to where its threads fray out; let this cylindrical case be of a dark-brown color, and leathery aspect, and ornamented with little starry knobs or warts, like raised embroidery—and then, so far as form is concerned, you have the Hyalonema, or glass-sponge of Japan.

It thus appears from the above that the structure has three parts—the buff-colored mass at one end, the long shaft of white threads, and the star-embossed case which envelops the axis or shaft. Now, what

Fig. 2.



Japanese Drawings of Hyalonema Sieboldi. (The artist, not knowing the facts in the case, has figured them in wrong position. Compare with Figure 1.)

is the material nature of each part? There is no difficulty about the buff-colored mass, in form like a cup. It has the spicules, and the sarcode, which characterize the sponge-flesh. The axis or coil is of pure translucent silex, like white threads of glass. The surrounding sheath, with the starry prominences, is of a horny or keratose material, much like the stems of the sea-fans, and it is a curious fact that this horn-like sheath is coated with a fine silicious powder, just as it would look if made of India-rubber, and while in the soft, adhesive condition dusted over with fine sand. With so much told, we are prepared for the curious scientific history of this interesting object, which bears a number of popular names, such as Glass-Plant, Glass-Coral, Glass-Rope, etc.

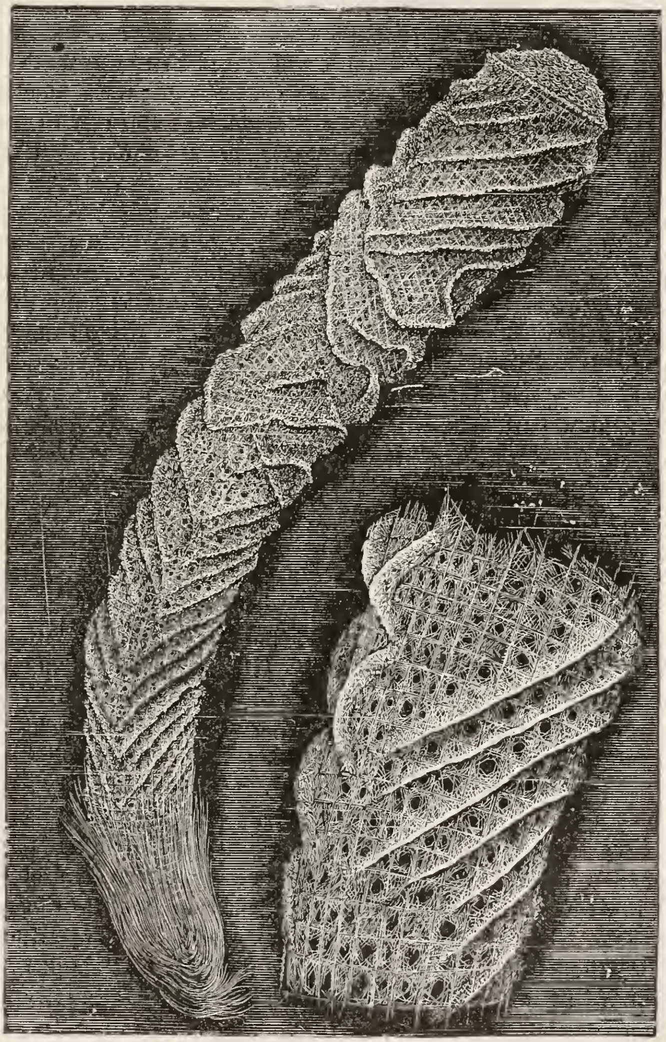
When the scientific men of Europe first made acquaintance with it, this object was an enigma, and for years the subject of much learned controversy. In 1835, some specimens, brought by the traveller Von Siebold, received special study by Dr. John E. Gray, of the British Museum, who named the object *Hyalonema Sieboldi*. On one point, to use a legal phrase, "each and every" of these learned men literally lost his head when studying this apparent abnormal nondescript; for they all alike stood the specimens on their heads, that is, they placed them, for study, theoretically upside down, namely, with the conical sponge heads, or masses, downward, and of course the coils of silica standing up. It must have been that the Japs themselves started this notion, in honest ignorance, as I believe; for in some natural-history engravings, done by native artists, which are now before me, these objects are portrayed, with the thread-like ends upward, and the sponge mass downward, and as if adhering to something (Fig. 2). This is curious, as the Japanese exhibit in their drawings a closeness in the observation of details that is almost scientific.[1] Dr. Gray's position made the sponge to grow on some object, or on the bed of the sea, and out of the sponge-mass so adhering, like a glass brush standing on its

[1] I am indebted to our Japanese students at New Brunswick for an explanation of the words on Fig. 2. They are the popular names of these objects in Japan. The cut gives three representations of Hyalonema, the Japanese Glass-Rope Sponge. The middle one of them in the original has the fascicles, or bundles of silicious threads, colored red, while the others are white. They are also represented as growing crowded together, some six or more in a group. The Conical Sponge masses, too, are flattened, as if they were adhering at the base to a rock. The fascicles, too, are naked, like the specimens that Japanese ingenuity has prepared for market; that is, they are devoid of any encrusting polyp case or bark. It is evident that the artist has drawn upon the popular understanding of the subject, and his own inner consciousness. The one with the red fascicles, the color being probably the outcome of a lively imagination, has the Japanese name *Aka-hossz*. The word *hossz* means a brush of long white hair, such as is used by the Buddhist priests, and is derived from the adjective *hosoi*, meaning fine, thin, delicate. *Aka* means red. The others, which have the usual white fascicles, are named *hoshi-kai*. The words *hoshi* and *hossz* seem to be interchangeable, as they are identically the same, but are changed in the spelling for some reason not apparent. *Hoshi*, then, means a brush of long white hair, and *kai* means a small bivalve. The word has that general application to mollusks and crustaceans which seems to carry with it the significance of our popular word shell-fish. The common name, then, of the Glass-Rope Sponge, in Japan, would seem to be *the Shell-fish with the brush of white hair*, or *the Long-white-haired Shell-fish*; and, as we have the anomalous expression, a white-blackbird, so the Japanese have the *Red White-haired Shell-fish*. Of course, no claim is here set up for philological accuracy, although the above is believed to be sufficiently correct for the purpose in hand.

S. L.

handle, and spreading out in the water, grew the zoophyte, as he regarded the silicious whisp, and its bark-like envelop. Now, among the polyps, known as Alcyonarians, is the Gorgonia, or Sea-fan, which has an axis of a horn-like nature, and a crust of lime; so he made of this polyp, which he supposed constructed the axis and the case, an Alcyonarian, allied to those polyps which build the Sea-fans. But the difficulty was that, instead of a centre or core of keratose, with an

Fig. 3.



Euplectella Speciosa. The Venus Flower-Basket: A Glass Sponge. That on the right is a portion of the natural size, intended to show the lace-like meshes. The full figure is about half the natural size.

envelop of lime, this had a core or axis of silica, and a bark of keratose. According to Dr. Gray, the Hyalonema was really two animals, namely, the polyp, represented by the glass coil, and its horny crust; and the sponge, represented by the conical spicular mass, which as a new species he named *Carteria.*

Prof. Milne-Edwards, in 1857, described the sponge-mass and the glass-rope as but one animal, and "degraded the zoophyte to the rank of an incrusting parasite."

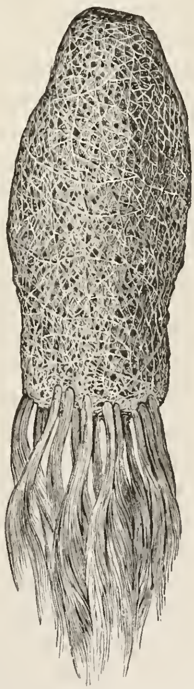
In 1859 appeared the magnificent work of Dr. Brandt, of St. Petersburg, on the Hyalonema. Now, the tables are completely turned. The silicious rope, and its warty bark, are declared to be parts of a polyp, and the sponge is announced as the parasite!—"attaching itself to the polyp, gradually penetrating its silicious axis, and finally killing it." Poor, innocent sponge! Even at the risk of being unparliamentary, we rise to brand that statement as a libel on the sponge.

In 1860 appeared the elaborate memoir on the Hyalonema by Prof. Max Schultze, of Bonn. He describes the glass-coil and the sponge-mass as belonging to one and the same animal structure. The warty crust, or case, he refers to a distinct animal, a polyp to which he gives the name *Palythoa fatua.* Schultze, however, makes the polyp a "commensal" with the sponge; that is, they both live at the same table, which means that the sponge, by its ciliary action, has to supply food for both. Schultze's exposition is the generally accepted one. His idea of commensalism, however, the present writer cannot accept. Nor can he accept Milne-Edward's degradation of the zoophyte to a parasite. But want of room will not permit a statement here of the reasons of his disbelief.

The curious fact made clear is that, through all these years of earnest investigation, Hyalonema was studied upside-down, until Prof. Lovén published his ingenious paper (in 1867, we think), in which, by a little stalked pyriform deep-sea sponge, he demonstrated the true position or attitude in life of the Hyalonema. In 1870 Prof. Joseph Leidy attained the same conviction from a different line of argument. It was pretty much as if one should ask, "Should a house stand on its chimney?" Says Dr. Leidy: "It has occurred to me that the sponge-mass, in its natural position, was uppermost, and was moored by its glassy cable to the sea-bottom; this opinion is founded on the circumstance that in sponges generally the large oscules from which flow the currents of effete water are uppermost." In fact, these glassy threads, at their lower extremities, spread out in a spiral manner, much like the spray from a turbine water-wheel, and, thus penetrating the mud, afford a good anchorage. This mooring is greatly helped, too, by the peculiar structure of these long silicious needles. These needles, or glassy threads, are, in the body of the fascicle, or skein, cylindrical, and smooth; but, toward their extremities, they are rugose, having almost imbricating rings. Beheld for the first time under the microscope, its sight recalled the appearance of the hairs of a bat. I have convinced myself that this is the functional intention of the frayed end of the fascicle, by a careful examination of a suite of specimens obtained for me at Enosima, Japan, by Prof. Griffis, of the Imperial College at Yeddo.

But the deep-sea dredging described in Dr. Thompson's book sheds much light on the Hyalonema. Says the writer: "When we trace its development, the coil loses its mystery. In two or three hauls we got them in every subsequent stage—beautiful little pear-shaped things, a centimetre long, with a single osculum at the top, and the whisp like a small brush. At this stage the *Palythoa* is usually absent, but, when the body of the sponge has attained 15 mm. or so in length, very generally a little pink tubercle may be detected at the point of junction between the sponge-body and the coil, the germ of the first polyp."

Fig. 4.



Pheronema Annæ. Half the natural size. A glass-sponge, obtained at Santa Cruz, W. I.

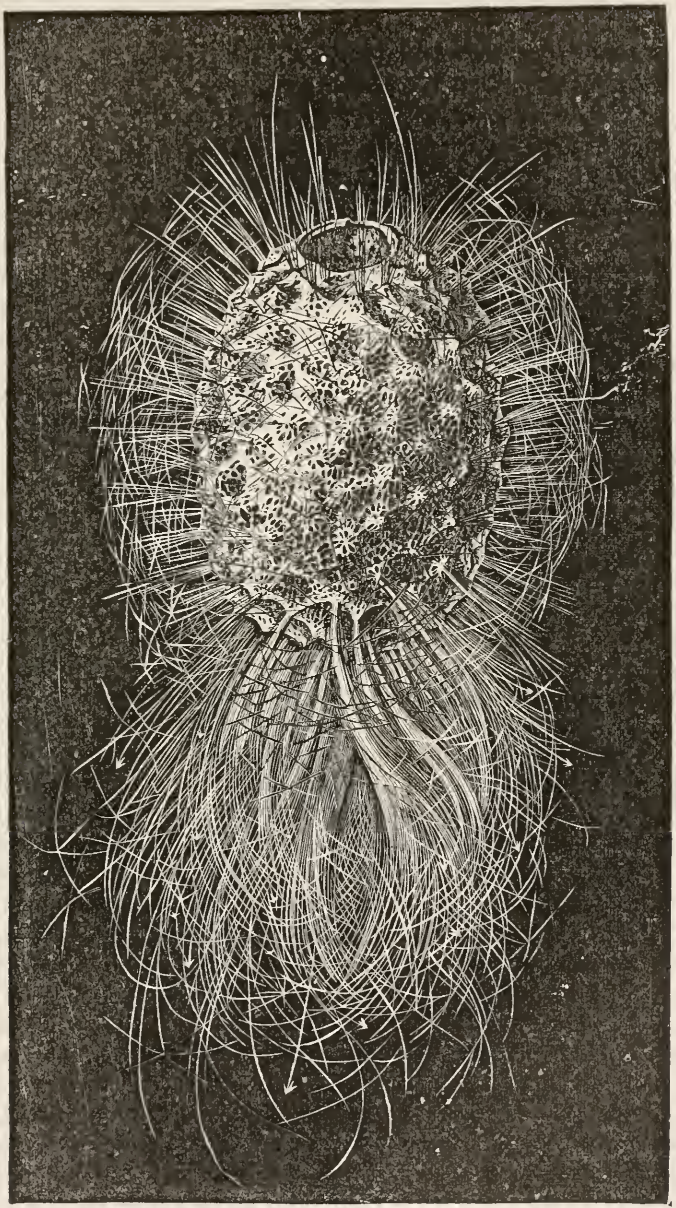
Allusion has been made to the ingenious manipulation of these glass-sponges by the Japanese. Says Dr. Hadlow, then in Japan: "We sometimes meet with portions of the glass coil most ingeniously attached to and grouped with corals, shells, and other marine products. . . . Such arrangements are entirely artificial, notwithstanding that they are often so artistically done as to have a most deceptively natural appearance."[1] The prettiest specimen of Hyalonema the writer ever saw, one worthy to be called *unique*, was a clever put-up job. Even to a part of the polyp encasement, from one end to the other, it was put together much as we have seen some fraudulent bird-stuffers put into the tail, wings, and even the crown of the head, feathers from other birds.

Hyalonema was the first of the glass-sponges known to science. It came among the *savants* as an anomaly of animal structure. Soon after appeared the Venus's Flower-Basket, the peerless beauty among the glass-sponges. In two remarkable respects it resembled its predecessor. Like Hyalonema, it was moored to the sea-bottom by glassy threads; and, like the pretty Glass-Rope Sponge, it made its *début* in scientific society standing on its head! It was actually so figured by Dr. Owen, its original describer, in the "Zoological Transactions of London." The name by which it is now known is well deserved by an object so lovely—*Euplectella speciosa.* The first of these words means well-woven, while the second intensifies the first, so that the meaning really is, the specially beautiful, well-woven (Fig. 3.)

It is almost hopeless to attempt a description of Euplectella in words. Nor has any artist yet done justice with his pencil to the delicate fabric. The first specimen that reached England, and which for a long time was the only one known, was purchased by William J. Broderip, for the sum of $150 in gold. Says Prof. Owen: "Mr. Cuming has intrusted to me for description one of the most singular and beautiful, as well as the rarest of the marine productions." Euplectella is in form a cornucopia, at the lower end about an inch in diameter, and in good specimens, after making a graceful curve, terminating at top in a width of nearly two inches. This part has a cover with a frilled edge, which, in a complete specimen, projects about a fourth of an inch over the sides. The bottom, or smaller end, is encompassed with a dense ruff of glass threads, so delicately white, flexible, and fine, that they look like a tuft of floss-silk. This muff-like surrounding is sunk into the deep-sea ooze, the fibres pointing up, which, though effectual, is certainly an odd way of mooring itself. In this manner this sponge is, when living, in a perpetual bath of mud. Like Hyalonema, our Euplectella is an anchoring sponge. Venus's Flower-Basket looks like a structure made of spun-glass; and so fragile that one hesitates to take it into the hands. It is wonderfully light—reminding, in this respect, of the skeleton or phantom flowers sometimes seen under glass. But Euplectella, although really so delicate, is quite strong. The threads which make up this fabric of woven

[1] "The Hyalonema Mirabilis." Read, October 30, 1872, before the Asiatic Society of Japan, by Henry Hadlow, Surgeon R. N. Printed in the *Japan Weekly Mail*, March 1, 1873.

FIG. 5.



ROSSELLA VELATA, natural size. A glass-sponge dredged off the Strait of Gibraltar in 651 fathoms.

glass are so flexible that a body is led to wonder if this is like the product of that lost art. To us it seems doubtful whether any woven glass, the product of art, can quite affect the singular lustre that belongs to these silicious threads spun from Nature's distaff. Each thread, although of pure silica, and solid, is really composed of a series of concentric tubes or cylinders, as if spun on a central thread or core. The effect, as respects the light, is not easily described. As the threads are composed of pure silica, one might suppose that they would be transparent, as a film of pure white glass of equal thickness. Such is not the fact. They are translucent, and have just an appreciable tint of the opal. It is this that imparts to Euplectella that softness of aspect which has been called "a delicate satiny lustre." To us the term opalescent seems better. We have a specimen which, in a good light, shows the play of colors that frozen crispy snow does in the moonlight.

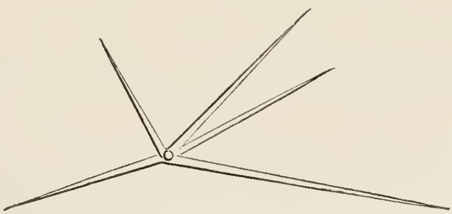
As to the idea "well-woven," which the name contains, the fabric really seems to have its web and its woof. There are long threads that traverse the whole length; and there are others that cross and interlace, or, more correctly, interweave. And, what no loom of human invention has ever done, this lowly weaver makes the fabric as it progresses take on the most quaintly little flounces with the most delicate frilled edges imaginable; and all arranged in such charming grace and ease—not in parallel circles, like hoops on a barrel, but in tasteful, easy-flowing curves. In the configuration of the innumerable forms of structure, Nature, as she ascends in the grade of her work, almost abandons her parallels in the outlining and ornamentation of her constituted things. In the mineral province the structure of crystals shows her delight in parallel, straight lines. The curve is a rarity there. But in organic forms the curve is the rule, and the straight line is the exception. The lace-like structure of the Euplectella is so aërial a fabric, and so quaintly graceful, and, as one might say, so deftly done in the putting together, that any embroidery would seem in the comparison bungling. Enflounced in its own tiny, crispy frills, there is an air of improvised beauty. And there is a flavor of rank in the almost grotesque hint thrown out by the sometimes queer sort of relief afforded in this excess of elegance by a dash of chevron-work.

Euplectella is chiefly got from the Philippine Islands. The natives have their own notions, it seems, about this marvellous object. They will tell you that this beautiful sponge is found in pairs, and that they are the work of little crabs, who, they believe, build these houses while living inside them. It is a remarkable fact that generally in these glass cornucopias, as if they were cages, a pair of little crabs dwell together. How they ever got inside nobody knows. Can it be that they are silly enough to wall themselves up in this limbo of silica? Not they, although they do have nippers and thumbs. A much lowlier creature, fingerless, and for that matter organless, uprears these fairy structures. However, the fact is indisputable. There they are, incased in glass, and beyond the possibility of deliverance. Were these little folks communicative, and not so crabbed, one might ask if they acted out the moral of the adage about people who live in glass houses. There is little doubt that this imprisonment is voluntary. We think these crabs are true commensals. Whether welcome or not, they always eat at the Euplectella's table. Lest we should seem to be muddling the work of the systematists, we would be understood metaphorically, when stating our positive conviction that these crabs are sponges from their very birth.

A new glass-sponge, obtained from the island of Santa Cruz, W. I., is described by Prof. Joseph Leidy, in the *American Naturalist* for March, 1870. Some description of it had already been given elsewhere. Its form is seen in Fig. 4. It will be remembered that the glass-rope sponge had one fascicle or bundle of glass threads. This sponge has at least twenty of these bundles, each about two inches long. These also are of silicious threads, and have the appearance of "tufts of blond human hair." It would not be strange should a lady naturalist liken them to skeins of *cuir*-color zephyr worsted; for, queer as this may seem, such would be an unconscious guessing of the name which this new sponge has received. Pheronema means the *skein-bearer*. "In honor of his wife," Prof. Leidy "has dedicated the species under the name of *Pheronema Annæ*.

The names of this trio of wonderful sponges are, it will be seen, expressive, euphonious, and picturesque — Hyalonema, the glass, or hyalene skein — Euplectella, the accomplished weaver — Pheronema, the skein-bearer.

Fig. 6.



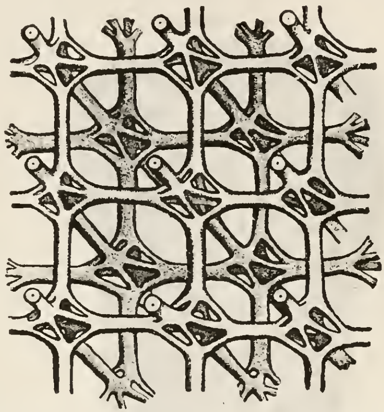
A Group of United Spicules in Pheronema.

And now, like wresting jewels from the land of Ind, the naturalist has found that these inimitable gems are of many kinds and abundant, but locked up in the hitherto unapproachable coffers of the deep sea. First, the Norwegian scientist invaded this domain, and bore off amazing treasures. Then the Americans tried these great depths, and brought up gems that amazed the eyes of the naturalist. Then came the English expeditions, tolling the ocean treasury at the astounding depth of 15,000 feet! It is now found that the congenial home of the glass-sponges is the emphatically deep water. There are precious stores of exquisite forms and structures, that have never been seen by any except their Creator. One of these, described in Dr. Thompson's book, which was obtained during the cruise of the Lightning, is named in honor of M. Holten, the Danish governor at Faroe, and Prof. Carpenter—hence the appellation *Holtenia Carpenteri*. It is about nine inches long, and three and a half inches wide. The body of this glass-sponge is of an oval, or egg-shaped form. At the bottom is a great mass of fine silicious threads, like white hairs, wadded together like a mop. These are its anchoring threads. There is a crater, or oscular opening at top, about three-fourths of an inch wide, around which, on the outside, short threads of silica stand out, not unlike a beard. Thus the upper part of the sponge might be likened to a bird's-nest. Hence the Setubal deep-sea shark-fishers, who sometimes bring them up from great depths with threads of Hyalonema on their fishing-lines, call them "sea-nests." The spicules are arranged in little stellate groups, the effect being that the entire surface of the sponge has an ornamentation of stars.

We can mention but one more of these singular beings. This is the *Rossella velata*, Fig. 5. And here we will borrow Dr. Thompson's own words: "On August 30, 1870, Mr. Gwyn Jeffreys dredged in 651 fathoms in the Atlantic off the mouth of the strait of Gibraltar an exquisite sponge, resembling *Holtenia* in its general appearance, but differing from it in the singular and beautiful character of having a delicate outer veil, about a centimetre from the surface of the sponge, formed by the interlacing of the four secondary rays of large five-rayed spicules, which send their long shafts from that point vertically into the sponge-body. The surface of the sponge is formed of a network of large five-radiate spicules, arranged very much as in *Holtenia*; but the spicules of the sarcode—the small spicules which are embedded in the living sponge-jelly—are of totally different form. A single large 'osculum' opens, as in *Holtenia*, at the top of the sponge, but instead of forming a cup uniformly lined with a netted membrane, the oscular cavity divides at the bottom into a number of branching passages, as in *Pheronema Annæ*, described by Dr. Leidy. The spicules of the 'beard' are more rigid and thicker than those of *Holtenia*, and scattered among them are some very large four-barbed grappling-hooks." Such is the capital description of the learned naturalist. To be sure, some old "salt" would be more laconic; for he doubtless would tell you that it was like a pine-apple, with the crown and its core removed.

We have tried to make plain what is meant by sponge-flesh, for which the word sarcode is used. It should be understood that this sarcode, which is a semi-fluid substance, is simply held to the mesh-like skeleton and to itself by the interlacing of tiny needles of flint, called spicules, so that the albuminous-like flesh is really felted together. From the sponge of the toilet this sarcode and its spicules have been all removed. The interesting fact is that, while these spicules are arranged in different patterns, many being made to radiate like stars, no two species have the same pattern. Look at Fig. 6, which represents the spicules of *Pheronema.* It looks as if

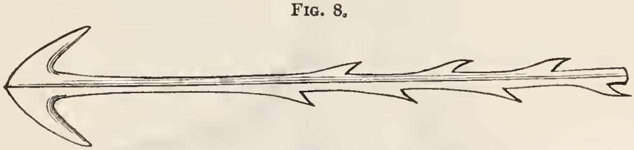
Fig. 7.



Section of the Outer Wall of Ventriculites Simplex, showing the structure of the silicious net-work. Magnified 50 times.

the series were united together to make an irregular star. Now, one of these needles sticks perpendicularly into the sarcode, leaving the other rays to spread out in a plane, to which the one that serves as a spike is perpendicular. One might liken it to a parasol without its silk covering—the handle in the hand is the spike, and the steel ribs

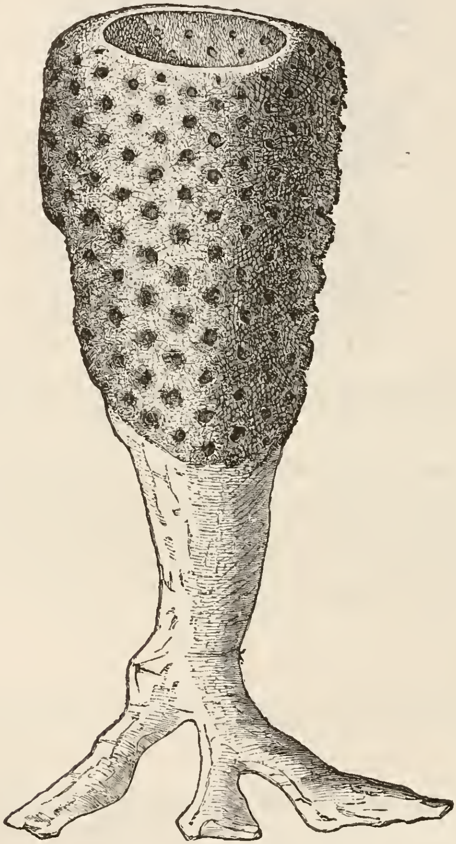
Fig. 8.



Extremity of a Mooring-Thread of Pheronema, showing the notched sides and the anchor-flukes at the end. Greatly magnified.

spread out will represent the silicious rays, or spicules. At a little distance from this penetrating needle, or spike, the needle of another of these irregular stars pierces the sarcode. Of consequence, the radiating needles, or spicules, of each one of these irregular stars lock into the similar spicules of the adjoining star, and so on for the entire mass, until it has the effect of felt; with this great difference, however—so regular is this natural felting of the sponge-flesh—that the whole mass is spiculated or laid out in quite regular and pretty patterns; and such is the uniformity of pattern for each kind that they actually mark the difference of species. As evidence of this regularity and beauty, look at the engraving of the spicular pattern of a fossil glass-sponge (Fig. 7). Now, it should be observed of the sponges which we have given in detail, that their spicules are arranged on a six-rayed plan, or, as sometimes expressed, hexradiate. Accordingly, Prof. Oscar Schmidt has "defined the group as a family under the name *Hexactinellidæ.*"

Fig. 9.

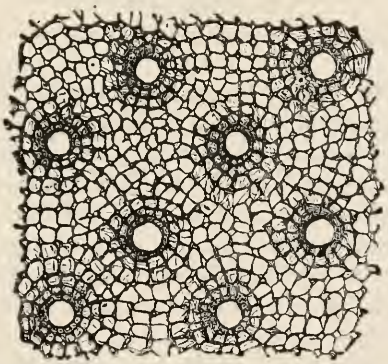


Ventriculites Simplex.—A fossil sponge, once and a half the natural size, showing the surface ornamented by a regular arrangement of ventricles. (*See* Fig. 10.)

Many of these glass-sponges have the habit of mooring themselves by their silicious threads, and on this account are called "anchoring sponges." Though acting in this matter on one general principle, yet they have diversities of ways in carrying out this law of their nature. *Hyalonema*, the glass-rope sponge, plunges its long threads down into the mud, and then spreads them out like a brush. These threads have a ringed structure, so that each one has an individual hold, or purchase, like that of a screw. Venus's Flower-Basket has the small end of the cornucopia plunged deeply into the sea-ooze, and from its extreme end threads go out with an upward and outward curve. Thus the mud rests upon them on the inside of the curves, and holds the dish-shaped tuft of fibres down. *Pheronema* has its threads near the extremities marked by projecting notches, while at the very extremity it is actually anchor-shaped, as shown by a thread magnified (Fig. 8). *Holtenia* has a great mop of fine roots, like what is often seen when changing a plant from one flower-pot to another. *Rossella* has a great outlay of mooring-threads, with frequently a line quadrate-barbed at its extremity. This is well shown in Fig. 5. These lines have actually at the bottom a four-hooked grapnel.

A very interesting fact is this: The study of these *Hexactinellidæ* has made clear as light the structure and character of the curious flinty fossils obtained from the cretaceous formation, and known as *Ventriculites.* Fig. 9 shows one of these fossils, and Fig. 10 shows its beautiful spicular structure. It is now plain that they were glass-sponges, and also belonged to the family *Hexactinellidæ;* while the deep-sea dredging, as it brings up these so-long-concealed witnesses, is proving that our notion, that the cretacean forms of life belonged wholly to the great past, needs careful revision; for it may be that this ante-biotic theory is not quite correct.

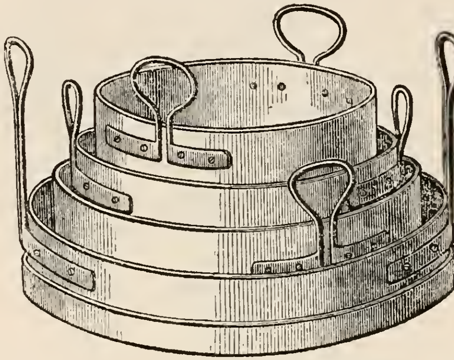
FIG. 10.



OUTER SURFACE OF THE FOSSIL SPONGE, VENTRICULITES SIMPLEX, magnified four times, showing the ventricles which make the outer ornament. (*See* Fig. 9.)

And there are many strange and also beautiful forms of life that are the companions of these deep-sea sponges. Yes, and even almost formless conditions of life are there. A substance like albumen, a sort of protoplasm, spreads over the broad acres of the sea-bottom. Perhaps it is the manna which Providence has given to these wonderful creatures that occupy these deserts beneath the sea. Certain it is that, in two senses, the dredger is plunging into the profoundest physical problems. How precious, then, is every grain of mud obtained from such depths! Hence the careful treatment it receives when brought on deck. Fig. 11 shows the sieves used. The whole nest of four is used at once. Some of the mud is put into the top one, which has large meshes, these meshes decreasing in size, so that the smallest are in the sieve at the bottom. The whole are set in a deep tub of sea-water. There is to be no turning round of the sieves, as that would break or bruise some of the frail organisms. Taking hold of the handles of the bottom sieve, the whole nest is lifted up and down with a gentle churning motion; and, when the mud is all passed through, the objects are tenderly removed to jars of sea-water. A bone forceps is used for this purpose.

Fig. 11.



The Sieves used in separating the Contents of the Dredge in Deep-sea Dredging.

What a wonderful, yea, fascinating thing, then, is this lovely glass-sponge! It is amazing that a creature so simple, that it has been called structureless, should surpass all other organisms in its capacity of rearing exquisite fabrics. And, now that we have had time to sober down a little in our raptures over its structural beauty, and, so to speak—like one that has passed from the pleasant contemplations of art to the graver meditations of philosophy—to listen with composure to its deeper teaching, we find it casting new light upon the inquiries of Science—even lifting a corner of the veil of the covered past. So little, until lately, did we know about the glass-sponge, that we were like the purblind prehistoric man working patiently at his flint nodule to fashion it into an implement for use, little dreaming that some glass-sponge had been the ancient eliminator and conservator of the solvent silex of the sea, and had, through subsequent geologic action, preserved its skeleton for the service of that ruder artisan. What a freight of precious knowledge will that be, when the good ship Challenger shall have returned from her four years' dredging around the world, among that newly-opened "Abyssal Fauna," whose province covers 140,000,000 square miles beneath the blue mantle of "the myriad smiling sea!"

THE CONSTITUTION OF MATTER.

By FERNAND PAPILLON.

TRANSLATED BY A. R. MACDONOUGH.

WHATEVER empirics and utilitarians may say of them, there are certainties apart from the experimental method, and there is progress disconnected with brilliant or beneficent applications. The mind of man may put forth its power in laboring in harmony with reason, yet discover genuine truths in a sphere as far above that of laboratories and manufactures as their sphere is above the region of the coarsest arts. In a word, there is a temple of light that unfolds its portals to the soul neither through calculation nor through experiment, which the soul nevertheless enters with authority and confidence, so long as it holds the consciousness of its sovereign prerogatives. When will professed scientists, better informed of the close connection between metaphysics and science, whence our modern knowledge of Nature has sprung, better taught in the necessary laws that govern the conflict of reason with the vast unknown, confess that there are realities beyond those they attain? When will science, instead of the arrogant indifference it assumes in presence of philosophy, admit the fertility beyond estimate of the latter? It may be that the hour of this reconciliation, so much to be longed for, is less remote than many suppose; at least, every day brings us nearer to it. The spirit of Descartes cannot fail to arouse before long some genius mighty enough to revive among us a taste and respect for thought in all the departments of scientific activity. Deserted as high abstractions are for the moment, they are not, thank Heaven, so utterly abandoned as to deprive study of its ardor, and essays of their success, when these relate to the problem of the constitution of matter. In fact, this is a question which for several years past has occupied some among our own *savants* and thinkers, as completely as it has employed most of those of the rest of Europe, a question which bears witness with peculiar eloquence to this fact, that, if philosophers are forced to borrow largely from science, in its turn science can retain clearness, and elevation, and strength, only by drawing its inspiration from, and recognizing its inseparable connection with, the abstract consideration of hidden causes and of first principles.

I.

Matter is presented under a great variety of appearances. Let us consider it in its most complicated state, in the human body, for instance. In this, ordinary dissection distinguishes organs, which may be resolved into tissues. The disintegration of the latter yields anatomical elements from which direct analysis extracts a certain number of chemical principles. Here the anatomist's work ends. The chemist steps in, and recognizes in these principles definite kinds arising from the combination, in fixed and determinate proportions, of a certain number of principles that cannot be decomposed, substantially indestructible, to which he gives the name of simple bodies. Carbon, nitrogen, oxygen, hydrogen, sulphur, phosphorus, calcium, iron, which thus set a limit to experimental analysis of the most complex bodies, are simple substances, that is to say, they are the original and irresolvable radicals of the tissue of things.

We now know that matter is not indefinitely divisible, and that the smallest parts of the various simple substances existing in those that are naturally compound have not all the same dimensions, nor equal weights. Chemistry, by a course of analyses and measurements, has succeeded in determining the weights of atoms of the different elements, that is to say, taking as a unit an atom of the lightest element, hydrogen, in determining the weight of the atoms which are equivalent to this conventional unit in the various combinations. Though many *savants* continue to maintain that atomic weights are nothing but relations, and that the existence of atoms is a mere logical device, it seems more reasonable to admit, with the majority of those who have studied this difficult problem closely, that these atoms are actual realities, while it may be very far from easy to settle precisely their absolute dimensions. In any case, we may affirm that these dimensions are very much less than those presented by the particles of matter subjected to the most powerful and subtle methods of division, or decomposed by the imagination into its minutest elements. "Let man," says Pascal, "investigate the smallest things of all he knows; let this dot of an insect, for instance, exhibit to him in its diminutive body parts incomparably more diminutive, jointed limbs, veins in those limbs, blood in those veins, in that blood humors, and drops within those humors—let him, still subdividing these finest points, exhaust his power of conception, and let the minutest object his fancy can shape be that one of which we are now speaking—he may, perhaps, suppose that to be the extreme of minuteness in Nature. I will make him discover yet a new abyss within it. I will draw for him not merely the visible universe, but all besides that his imagination can grasp, the immensity of Nature, within the confines of that imperceptible atom." In this Pascal displays a feeling as true as it is deep of the infinitely small, and it is interesting to observe how the amazing revelations of the microscopic world have justified his eloquence and foresight; and yet this microscopic world, whose minutest representatives, such as vibrios and bacteria, are hardly less than the ten-thousandth part of $\frac{1}{25}$ of an inch, how coarse it is compared with the particles thrown off by odorous bodies, and with the inconceivably minute quantities which chemistry, physics, and mechanics, now measure without seeing them, or make their existence plain without grasping them! We may mention some instances which can give us an idea of these.

According to Tyndall, when very minute solid particles, smaller than the luminous waves, are diffused in a medium traversed by light, the light is decomposed in such a way that the least waves, the blue ones, predominate in the reflected rays, and the largest ones, the red waves, in the transmitted rays. This ingenious physicist thus explains how the blue color of the sky depends and must depend on the existence of solid particles, excessively minute, diffused in infinite quantity through the atmosphere. Tyndall is not disinclined to the idea that these imperceptible atoms might very well be no other than those germs of microscopic organisms the presence of which in the atmosphere has been proved by the labors of Pasteur, as well as the part they take in the phenomena of putrefaction and fermentation. The ova of these beings, which are barely visible under the microscope after attaining full development, and of which the number, ascertained by the most decisive evidence, confounds the boldest imagination, these would be the elements of that vital ether, as we have termed it, that dust which gives its lovely blue tint to the vault of the sky. "There exist in the atmosphere," Tyndall says in closing, "particles of matter that elude the microscope and the scales, which do not disturb its clearness, and yet are present in it in so immense a multitude that the Hebrew hyperbole of the number of grains of sand on the sea-shore becomes comparatively unmeaning." And to give an idea of the minuteness of these particles, Tyndall adds that they might be condensed till they would all go into a lady's travelling-bag. Manifestly these particles escape any kind of direct measurement and observation. Their objective reality can no more be demonstrated than that of the particles of ether can be made evident. Yet there are certain facts which aid us to form a clear conception of them. Let us dissolve a gramme of resin in a hundred times its weight of alcohol, then pour the clear solution into a large flask full of pure water, and shake it briskly. The resin is precipitated in the form of an impalpable and invisible powder, which does not perceptibly cloud the fluid. If, now, we place a black surface behind the flask, and let the light strike it either from above or in front, the liquid appears sky-blue. Yet, if this mixture of water and alcohol filled with resinous dust is examined with the strongest microscope, nothing is seen. The size of the grains of this dust is much less than the ten-thousandth part of $\frac{1}{25}$ of an inch. Moren makes another experiment, proving in a still more surprising way the extreme divisibility of matter: Sulphur and oxygen form a close combination, called by chemists sulphuric-acid gas. It is that colorless and suffocating vapor thrown off when a sulphur-match is burned. Moren confines a certain quantity of this gas in a receiver, places the whole in a dark medium, and sends a bright ray of light through it. At first nothing is visible. But very soon in the path of the luminous ray we perceive a delicate blue color. It is because the gas is decomposed by the luminous waves, and the invisible particles of sulphur set free decompose the light in turn. The blue of the vapor deepens, then it turns whitish, and at last a white cloud is produced. The particles composing this cloud are still each by itself invisible, even under strong microscopes, and yet they are infinitely more coarse than the primitive atoms that occasioned the sky-blue tint at first seen in the receiver. In this experiment we pass in steady progress from the free atom of sulphur parted from the oxygen-atom by the ether-waves to a mass apparent to the senses; but, if this mass is made up of free molecules which defy the strongest magnifiers, what must be the particles which have produced those very molecules!

A last instance of another kind will complete the proof as to the minuteness of the elements of matter. When a clear solution of sulphate of aluminum is poured into an equally clear solution of sulphate of potassa, the mixture at once grows turbid, and after a few seconds myriads of little crystals, sparkling like diamonds, make their appearance in the liquid, which are nothing else than crystals of alum. If we suppose the diameter of these crystals to be $\frac{1}{25}$ of an inch, it will follow from this experiment that in the lapse of a few seconds crystals had the power of producing themselves containing tens of millions of molecules, each composed of 94 atoms, grouped in admirable harmony. The motions of these chemical atoms take place under the influence of the same forces that guide the motions of those enormous agglomerations of atoms called stars. The revolution of one sun around another takes a thousand years, while these atoms in course of combination perform hundreds of millions of such revolutions in the millionth part of a second!

By varied and delicate calculations, Thomson has succeeded in establishing the fact that, in liquids and transparent or translucent solids, the mean distance between the centres of two contiguous atoms is comprised between the ten-millionth and the two-hundred-millionth part of $\frac{1}{25}$ of an inch. It is not easy to form an exact conception of dimensions so small, of which nothing, among the objects that affect our senses, can convey any idea. Thomson judges that the following comparison may aid us to appreciate them: If we imagine a sphere as large as a pea magnified, so as almost to equal the earth's volume, and the atoms of that sphere enlarged in the same proportion, they will then have a diameter greater than that of a shot, and less than that of an orange. In other words, an atom is to a globe the size of a pea what an apple is to the terrestrial globe. By arguments of quite another kind, drawn in part from the study of chemical molecules, in part from the phenomena of capillarity, Gaudin has ascertained, for the dimension of the smallest particles of matter, figures very nearly the same as Thomson's. The maximum distance apart of the chemical atoms in molecules is the ten-millionth part of $\frac{1}{25}$ of an inch. Gaudin follows Thomson in the attempt to give some sensible notion of the truly amazing minuteness of a dimension like this. He calculates, upon this estimate, the number of chemical atoms contained in about the size of a pin's-head, and he finds that the number requires for its expression the figure 8 followed by twenty-one ciphers. So that, if we attempted to count the number of metallic atoms contained in a large pin's-head, separating each second ten millions of them, we should need to continue the operation for more than 250,000 years!

There are, then, atoms in matter, and atomism is a fact, whenever we rest in the affirmation of the existence of atoms. But these are not the real principles, the simple and irreducible elements of the world. After decomposing sensible matter into atoms, we must subject the latter to an analysis of the same kind. Let us, then, consider any two heterogeneous atoms whatever, an atom of iron and an atom of hydrogen, for instance, and examine in what respect they can really, essentially, differ from each other. What is it which at bottom truly distinguishes these two atoms, as atoms? It is not any peculiarity of form, solidity, fluidity, hardness, sonorousness, brightness, because these properties evidently depend on the mutual arrangement and disposition of atoms, that is, because they are not relative to the individuality of each atom, but to that of the whole which they form by being grouped together. Neither is it any caloric property, or optic, or electric, or magnetic one, because these properties result from the movements of the ether, within the more or less complex aggregate of the respective atoms of these two substances. Now, if these atoms, taken separately, differ from each other in virtue of none of the properties just enumerated, they can only be dissimilar as regards two attributes, dimension and weight; but difference in weight results from difference in dimension, and is not a qualitative difference, but simply a quantitative one. Consequently, any two heterogeneous atoms whatever, compared together, as atoms, have scarcely any of the differential attributes peculiar to the groups which they make up by aggregation, and represent no more than two distinct functions, two different values of one and the same initial matter, of one and the same primitive quality or energy. This simple demonstration establishes the unity of substance, not as a more or less plausible physical hypothesis, but as a metaphysical certainty, alike underivable and necessary. If we add now, reserving the demonstration for a later period, that dimension, corporeal extension itself, as Leibnitz said and as Magy has lately proved, is only a resultant of force, it will become evident that matter, in the last analysis, is reduced to force.

Tyndall, in his biography of Faraday, tells us that one of the favorite experiments of this physicist gives a true image of what he was: "He loved to show how water, in crystallizing, eliminates all foreign substances, however intimately mingled they may be with it.

Separated from all these impurities, the crystal becomes clear and limpid." This experiment is especially the true image of what Faraday was as a metaphysician. For him nothing had so great a charm as those serene transparent regions, in which science, cleared of impurities, appeared to his great mind in all the glory of its power and splendor. He yielded himself to it with absolute abandonment. He particularly loved to dwell upon the problem which is now engaging us: "What do we know of an atom apart from force?" he exclaims. "You conceive a nucleus which may be called *a*, and you surround it with forces which may be called *m;* to my mind your *a* or nucleus vanishes, and substance consists in the energy of *m*. In fact, what notion *can* we form of a nucleus independent of its energy?" As he holds, matter fills all space, and gravitation is nothing else than one of the essentially constitutive forces of matter, perhaps even the only one. An eminent chemist, Henry Saint-Claire Deville, lately declared that, when bodies deemed to be simple combine with one another, they vanish, they are individually annihilated. For instance, he maintains that in sulphate of copper there is neither sulphur, nor oxygen, nor copper. Sulphur, oxygen, and copper, are composed, each of them, by a distinct system of definite vibrations of one energy, one single substance. The compound, sulphate of copper, answers to a different system, in which the motions are confounded that would produce the respective individualities of its elements, sulphur, oxygen, and copper. Moreover, Berthelot long ago expressed himself in exactly the same manner. As long ago as 1864 that *savant* said that the atoms of simple bodies might be composed of one and the same matter, distinguished only by the nature of the motions set up in it. This decisive saying a great number of *savants* and philosophers in France and abroad have repeated and are still repeating, with good reason, as the expression of a solid truth.

If the smallest parts which we can imagine and distinguish in bodies differ from each other only by the nature of the motions to which they are subjected, if motion alone rules and determines the variety of different attributes which characterizes these atoms, if in a word the unity of matter exists—and it must exist—what is this fundamental and primary matter whence all the rest proceed? How shall we represent it to our minds? Every thing leads to the belief that it is not essentially distinguished from the ether, and consists in atoms of ether more or less strongly held together. It is objected that the ether is imponderable; but that is an unfounded objection. Doubtless it cannot be weighed; to do that we must compare a space filled with ether to a space empty of ether; and we are evidently unable to isolate this subtle agent, whose particles counterpoise each other with perfect equilibrium throughout the universe. Yet many facts attest its prodigious elasticity. A flash of lightning is nothing more than a disturbance of equilibrium in the ether, yet no one will deny that lightning performs an immense work. However this may be, it is impossible to think of the energies that make up the atom otherwise than as of pure force, and the ether itself, whose existence is demonstrated by the whole of physics, can be no otherwise defined than by the attributes of force. It follows from this that atoms, the last conclusion of chemistry, and ether, the last conclusion of physics, are substantially alike, although they form two distinct degrees, two unequal values, of the same original activity. All those physico-chemical energies, as well as the analogous energies of life, only show themselves to us, save in rare exceptions, clothed with that uniform we call matter. A single one of these energies shows forth, stripped of this dress, and bare. It rules all the others, because it knows them all without their knowing it. It is not power merely, but consciousness besides. It is the soul. How define it otherwise than as force in its purest essence, since we look upon it, as on the marble of the antique, in splendid nakedness, which is radiant beauty too?

Whether we consider coarser matter which can be weighed and felt, or that more subtle, lively, and active matter we call ether, or again the spiritual principle, which is energy simple, we have then always before us only harmonious collections of forces, symmetrical activities, ordered powers, more or less conscious of the part they play in the infinite concert for which the Creator has composed the glorious music. Let us set aside for a moment the variety of groupings which determine the succession and the manifold aspects of these forces, and there will remain, as constituent principles of the web of the universe, as irreducible and primordial ingredients of the world, nothing but dynamic points, nothing but monads.

The term of the rigorous analysis of phenomena is, definitively, the conception of an infinity of centres of similar and unextended forces, of energies without forms, simple and eternal. We ask what these forces are, and we assert in answer that it is impossible to distinguish them from motion. Force may be conceived, but not shaped to the fancy. The clearest and truest thing we can say of it is, that it is an energy analogous to that whose constant and undeniable presence we feel dwelling in our deepest selves. "The only force of which we have consciousness," says Henry Sainte-Claire Deville, "is will." Our soul, which gives us consciousness of force, is also the type of it, in this sense that, if we wish to pierce to the elementary mechanisms of the world, we are imperiously driven to compare its primal activities with the only activity of which we have direct knowledge and intuition, that is to say, with that admirable spring of will, so prompt and sure, which permits us every moment to create and also to guide motion.

Motion may serve to measure force, but not to explain it. It is as subordinate to the latter as speech is to thought. In truth, motion is nothing else than the series of successive positions of a body in different points of space. Force, on the other hand, is the tendency, the tension, which determines the body to pass continually from one to the other of these points; that is to say, the power by which this body, considered at any instant in its course, differs from the identical body at rest. Evidently this something which is in one of these two bodies and is not in the other, this something that mathematicians call the quantity of motion, which is transformed, on a sudden stoppage of motion, into a certain quantity of heat, this something is a reality, distinct from the trajectory itself; and yet nothing, absolutely nothing, outside of the inner revelation of our soul, gives us the means of understanding what this initial cause of the motive forces may be. The distinguished founder of the mechanical theory of heat, Robert Mayer, defines force to be "whatever may be converted into motion." There is no formula that so well expresses the fact of the independence and preëminence of force, nor so completely includes the assertion of the essential reality of a cause preëxisting motion. The idea of force is one of those elementary forms of thought from which we cannot escape, because it is the necessary conclusion, the fixed and undestroyable residue from the analysis of the world in the alembic of our minds. The soul does not find it out by discursive reasoning, nor prove it to itself by way of theorem or experiment; it knows it, it clings to it by natural and unconquerable affinity. We must say of force what Pascal said of certain fundamental notions of the same order: "Urging investigation further and further, we necessarily arrive at primitive words which cannot be defined, or at principles so clear that we can find no others which are clearer." When we have reached these principles, nothing remains but to study one's self with profoundest meditation, not striving to give an image to those things whose essence is that they cannot be imagined. From the most general and abstract point of view, then, matter is at once form and force, that is, there is no essential difference between these two modes of substance. Form is simply force circumscribed, condensed. Force is simply form indefinite, diffused. Such is the net result of the methodical inquiries of modern science, and one which forces itself on our minds, apart from any systematic premeditation. It is of consequence to add that the merit of having formulated it very clearly and noted its importance belongs to French contemporary philosophers, particularly to Charles Lévèque and Paul Janet.

II.

If the web of things, the essence of matter, is one single substance, who was the Orpheus under whose spell these materials gathered, ranged, and diversified themselves into natures of so many kinds? And, first of all, how can the extension of bodies proceed from an assembling of unextended principles? The answer to this first question does not seem difficult to us. Extension exists prior to matter. They are two distinct things, without any relation of causality or finality. Matter no more proceeds from extension than extension proceeds from matter. This simple remark suffices to settle the difficulty of conceiving how the dimension of objects results from a group of dynamic points which have no dimension. Extension existing before every thing else, it is quite clear that, when certain primal energies come into union to give rise, through a thousand successive complications, to phenomena and to bodies, what they really produce is not the appearance of extension, which is the mere shadow of reality, but it is that collection of various and diverse activities which enable us to describe and define phenomena and bodies.

It is no longer a subject of doubt, in the minds of *savants* who have got beyond experimentation, that extension is an image and a show rather than an essential constituent property of bodies. The extension of bodies is a phenomenon which takes its rise in the collision of force with our minds. Charles de Rémusat, so long ago as 1842, gave an original and remarkable demonstration of this. He maintains that force is the cause of extension, meaning by that that the sensation of extension is a modification of our sensibility, occasioned by forces analogous to those which produce sensations of a more complex kind. When you experience an electric shock, you are struck. Percussion is the sensation of contact, in other words, of impulsion by something that has extension. Now, in this instance, Rémusat says, the cause of percussion, electricity, has no extension. Therefore, he adds, either electricity is nothing, or else it is a force which affects us in a way that may be compared to the effect of extension. So that a force, wanting the usual appearances of extension, may produce the same effects on us that a solid body in motion does. Within a few years a profound metaphysician, Magy, has pointed out by new arguments that corporeal extension is merely a show which springs from the internal reaction of the soul against the impression made on the sensorium, and which the soul translates to outward bodies, by a law analogous to that which makes it localize in the separate organs of sense the impression which it has nevertheless perceived only in the brain. Each sensation of taste, smell, light, or sound, is a phenomenon of psychological reaction which occurs in the soul when it is teased with a certain degree of energy by nerve-action, which in its turn depends on an outward action; but there is no relation of resemblance between the latter and the sensation it provokes. The ether, which, by its vibrations in unison with the elements of our retina, produces sensations of light in us, has in itself no luminosity. The proof of this is that two rays of light meeting under certain conditions may annul each other, and produce darkness. Now, Magy maintains that the subjectivity of extension is of the same order with that of light. Extension in general is explained by purely dynamic reasons, as readily as that particular extension is which serves as a kind of support for luminous phenomena, which evidently result from vibrations of the unextended principles. Helmholtz, in his latest writings, fully adopts this doctrine of corporeal extension.

We thus see that there is no difficulty in reconciling extension with unextended forces, and the phenomena of extension with principles of action; but this is only the first part of the problem, and it becomes necessary now to ascend from these unextended forces and active principles to those more or less complex manifestations which make up the infinite universe, adorning space with imperishable variety. Let us imagine this universe filled with the greatest conceivable number of active principles, all identical, diffused uniformly throughout immensity, and consequently in a state of perfect equilibrium. All will be torpid in absolute repose, in which form without shape and force without spring will be as though they were not. Between a homogeneous, motionless substance, identical with itself throughout space at all points, and nihility, reason perceives no difference. In such a system, nothing has weight, for there is no attracting centre; heat is no more possible for it than light, since these two forms of energy are bound up with the existence of systems of unequal vibrations, of diversified media, and varying molecular arrangements. *A fortiori*, the phenomena of life will be incompatible with this universal unity of substance, this unchanging identity of force.

The objective existence of things, the coming into reality of phenomena, can only be conceived, therefore, as the work of a certain number of differentiations taking place in the deep of that universal energy of primal matter, which is the last result of our analysis of the world. Motion, of itself alone, is enough to explain a first attribute of that energy, namely, resistance, and its consequence, impenetrability; but this is only on the condition that this motion shall take place in various directions. Two forces urged in opposite directions, and coming to a meeting, manifestly resist each other. It is probably by collisions of this sort that those variable condensations of matter, and those heterogeneous groupings of which the world presents the spectacle, have been determined. A rotary movement, communicated to a mass without weight, can only engender concentric spheres, which gravitate toward each other in consequence of pressure by the interposing ether. The famous experiments of Plateau are decisive in this respect. That accomplished physicist introduces oil into a mixture of water and alcohol, having exactly equal density with the oil itself. He inserts a metallic strip into the midst of this mass of oil, which is free from the action of any force, and turns it about. The oil takes the form of a sphere, and, as soon as the rotation grows very rapid, breaks up, and parts into a number of smaller spheres. The celestial spheres were probably formed in the same way, and an exactly similar mechanical action produces those clear dew-drops, glittering like diamonds, on the leaves of plants.

All physical phenomena, whatever their nature, are at bottom only manifestations of one and the same primordial agent. We can no longer question this general conclusion of all modern discoveries, Sénarmont explicitly says, though it is, as yet, impossible to formulate with precision its laws and its particular conditions. If this be true, and we hope we have proved it to be so, it is plain that those conditional particularities of which Sénarmont speaks, that is to say, those diversified manifestations of the sole agent to which he alludes, can depend only on differences in the motions which impel it. Now, the very existence of these differences necessarily implies a coördinating and regulating intelligence; but how much more extreme is the necessity for such a cause in chemical phenomena, which display such endless complications issuing from that primal energy to which every thing in the last analysis is reduced! We have seen that the variety of those stable and homogeneous energies known under the name of simple bodies, the number of which is now increased to sixty, depends on the variety of the vibrations that each one of these little worlds performs. This is the earliest intervention of a principle of difference. This principle does not merely determine the multiplication of simple bodies; it also acts in any one element with such intensity that the same element can acquire very unlike properties and attributes. What things are more heterogeneous than the diamond and charcoal, or than common phosphorus and amorphous phosphorus? Yet charcoal and diamond are chemically identical, just as the two sorts of phosphorus are. These cases of isomery, which are quite numerous, attest with the strongest evidence the excessive variability of which combinations of force are capable. When we see the same elements, combined in the same weight-proportions, produce sometimes harmless substances, sometimes terrible poisons, in one case evolve colorless or dingy products, in another brilliant hues, we become convinced that primal matter is of little consequence in comparison with the weaver who arranges its threads, and knows beforehand what the aspect of the web will be. Besides, it is not alone in the whole that the formative principle is displayed; it shows forth also in the elements, considered individually, since every one of them exhibits tendencies, elective affinities, that bear witness to some obscure instinct toward harmonious completion.

There is not only a prodigious variety in the disposition of the atoms which make up molecules, and in the arrangement of the molecules among themselves, but this arrangement is governed, besides, by admirable geometric laws. The atoms that make up molecules are not heaped and flung together at random and in disorder; they enter into composition only in fixed proportions and in fixed *directions.* Marc-Antoine Gaudin has proved, in a late treatise devoted entirely to these refined inquiries, the existence of some of the most important laws in the geometry of atoms. This ingenious and persevering writer demonstrates that all chemical molecules, whether they are fitted to produce crystals or not, are formed by a symmetrical aggregation of atoms. The latter are arranged in equilibrium in two directions, perpendicular to each other, one parallel to the axis of grouping, and the other at right angles to that axis, so as always to compose a symmetrical figure. The most complicated bodies, so soon as they are brought under the law of definite proportions, and compose chemical species, are made up of molecules in which the atoms are grouped in prisms, in pyramids, in a word, in polyhedra more or less many-sided, but always of perfect regularity; so that, in this case, the differentiation is regulated with marvellous harmony.

We must now rise another degree, and pass from inorganic matter to living matter. What is it that distinguishes the latter from the former? When we make the answer depend on the results of direct experiment, nothing is easier than to establish the differential characteristics of living matter. In the first place, it is organized, that is, the anatomical elements, instead of being homogeneous and symmetrical in all points of their mass, are composed by the association of a certain number of different substances, in which carbon predominates, and which are termed immediate organic principles. Then these elements grow. At no time the same throughout, as to the substance which makes them up, they are in a state of unceasing molecular renewal, of constant metamorphosis, of simultaneous and continuous assimilation and disassimilation. Besides, the various properties these elements may exhibit, contractility, neurility, and so on, are, in consequence of the growing state that characterizes them, in so unstable a condition of equilibrium that the slightest variation in the surrounding medium is enough to occasion some change in the expression of their activity; in other words, they have excessive excitability and irritability. Such, at least, is the region within which physiology is limited; but the fact which it does not clearly enough bring out, yet the thing which is the distinctive mark of life, is the harmonious seeking for each other of all these vital monads, the disposition of biological energies to compose groups of which the end and the reason are found in what we call the individual. The differentiations of inorganic matter occur in molecules that are specific, in whatever bulk they are regarded. The differentiations of living matter take place only in individuals whose build and proportions are strictly determined. An iron bar, an iron crystal, and iron-dust, are all still iron. An organic substance fitted for life is nothing, whenever deprived of connection with an organism. It can display energy, can act; in a word, can be, so far as to be a living substance, only in virtue of taking place and rank in a certain whole, and assuming certain dependencies and connections with other more or less analogous substances. By itself it is not distinguished in essence from dead matter. It is raised to the rank and clothed with the dignity of life only from the time of its reception into that gathering of which the steps all move toward the same end, which is, the functional action of the organism, and the perpetuation of the species.

What takes place in the ovule is a miniature image of what takes place in the universe. The differentiations occurring in that mucous drop are a copy of the differentiations unfolding and expanding in the ocean of the world. It is at first a microscopic mass, homogeneous, uniform in all its parts, a collection of energies identical with each other, and the group of which does not differ perceptibly from a drop of gelatine, hanging, hardly seen, from a needle's point. Yet soon a dull motion spontaneously stirs these nearly inert atoms, and this motion is expressed by a first condensation of the ovular or vitelline substance, which is the germinating vesicle. This passes off, but at the same time other vibrations arrange the molecules of this shapeless, transparent microcosm, in the order of more complicated groups. The vitelline substance swells toward the surface, where it forms the polar globules, while at the centre it thickens to produce the vitelline nucleus. This in turn cleaves and breaks into a great number of secondary nuclei, around each of which the ovular mass distributes itself while contracting. Instead of a single cell, the ovule, which has enlarged, is now found to contain a great number. These cells, called blastodermic, then tend to arrange themselves in two layers, two leaflets placed back to back, within which the elements of the embryo appear, and little by little develop, pursuing a continuous growth, in which forces becoming forms go on incessantly producing and multiplying new forces and new forms.

Now, these separations and distributions, these orderings and classifyings, these harmonies that are set up in the ovule to compose by slow degrees the structure of the embryo, reveal a principle of differentiation analogous to that which has caused the infinite variety of things we see come forth from the confused mass of cosmic energies. There is, as many biologists had felt assured, and as Coste has had the glory of clearly demonstrating in a work which is one of the noblest scientific monuments of this age, there is a force which gives reality, direction, life, to the forms of organized matter in the egg. All eggs are alike at first. There is a complete similitude in structure and substance between those which will produce a lion and those which will produce a mouse. The forms are identical, though the future of those forms is different. It is, as Coste very well says, that "beneath that form, and beyond what the eye views, there is something which sight cannot reach, something which contains in itself the sufficient reason for all those differences now concealed under unity of configuration, and to become visible only later." This guiding idea, which Coste has brought forward, and which is admitted by all physiologists at this day, is as far from issuing out of the elementary forces of nutrition as the painter's picture is from being the creature of his palette. Yet nothing in the ovule reveals its hidden and potent virtuality. Claude Bernard, who has repeated Coste's ideas on this subject, dwells strongly on the guiding force which is in the egg, and those *savants* who agree with Robin in denying this force, so far as it acts on the totality of elements in the embryo, regard it at least as shared, distributed, and acting in each of these elements separately, which, at bottom, is the same thing. We see, in any case, that there is in the inmost depth, and there dates from the most rudimentary sketch of the organized being, the fixed and formed idea of those differences in choice and those sympathies in work whose system shall build up the individual. The differential coefficient of organized matter is thus of a far higher order than that of mineral matter. It is this which is a distinct and peculiar result from the impotence which experimental science betrays more plainly every day, when attempting to convert physico-chemical activities into energies of the vital order. Even could this conversion really be effected, and it is not metaphysically impossible that it might be, the existence of a spiritual principle of differentiation would be in no wise put in doubt. Hitherto, at least, such a conversion seems beyond the reach of man.

Something that yet more completely baffles his research, while commanding too his highest admiration, is the supreme degree of complexity together with refinement of that energy which is the soul. Human thought is the sum of all the forces of Nature, because it assimilates them all, while distinguishing between them, by the work that it performs upon sensations. Sensations are to thought what food is to growth. Growth is not a result of feeding; thought is not a result of sensations. Nutrition, in shaping the living organs, determines the differentiation of the concrete forms in the individual's substance; thought, in shaping general ideas, determines the differentiation of the abstract forces in the world. Thus thinking energy is as much superior to sensations as nutritive energy is to aliments. In another order of thought, we might compare the soul to a paper covered with writing in sympathetic ink. At ordinary temperatures, the letters are unseen, but they appear in fine color whenever brought near the fire. So the soul has within itself dim marks and confused shapes which sensation tints and brightens. We have seen that, in the mucous drop, a two hundred and fiftieth part of an inch through, called the ovule, the forces and tendencies of the whole nutritive and intellectual life of man lie prisoned and asleep. So, too, in that force without form or extension, which is the soul, there dwells a miniature picture of the whole universe, and, by some mystic grace of God, a dream, as it were, of that God himself. Thought consists in becoming acquainted with all the details of that picture in little, and unfolding its meaning. Thus, that which makes the whole reality of material things is form, and form, such as it is shown to us in the world, is at once a principle of differentiation and a principle of agreement; in other words, it is the work of an intelligence. Body and motion are mere phenomena. The first is only an image of substance, the last an image of action; but substance and action both are only effects of intelligent force, that is, of activity operating in view of a result. That activity, however, presents infinitely varied degrees of condensation, and we may say, with Maudsley: "One equivalent of chemical force corresponds to several equivalents of lower force; and one equivalent of vital force to several equivalents of chemical force." It is thus that modern science unties the gordian knot of the composition of matter.

III.

A first exclusively analytical view of the world has led us to a first undeniable certainty, the existence of a principle of energy and motion. A second view of the universe, exclusively synthetic, leads us, as we have seen, to another certainty, which is the existence of a principle of differentiation and harmony. This principle is what is called spirit. Thus spirit is not substance, but it is the law of substance; it is not force, but it is the revealer of force. It is not life, but it makes life exist. It is not thought, but it is the consciousness of thought. A distinguished English *savant*, Carpenter, has said lately, with decisive clearness, "Spirit is the sole and single source of power." In a word, it is not reality, yet in it and by it realities are defined and differentiated, and consequently exist. Instead of saying that spirit is a property of matter, we should say that matter is a property of spirit. Of all the properties of matter, in fact, there is not one, no, not a single one, which is not bestowed on it by spirit. The true explanation, the only philosophy of Nature, is thus a kind of spiritualistic dynamism, very different from materialism, or from the mechanism of certain contemporary schools.

Materialism is false and imperfect, because it stops short at atoms, in which it localizes those properties for which atoms supply no cause, and because it neglects force and spirit, which are the only means we have, constituted as our souls are, of conceiving the activity and the appearings of beings. It is false and imperfect, because it stops half-way, and treats compound and resolvable factors as simple and irreducible ones; and because it professes to represent the world by shows, without attempting to explain the production of those shows. In a word, it sees the cause of diversity where it is not, and fails to see it where it does exist. The source of differentiations cannot be in energy itself; it must be in a principle apart from that energy, in a superior will and consciousness, of which we have doubtless only a dim and faulty idea, but as to which we can yet affirm that they have some analogy with the inner light which fills us, and which we shed forth from us, and which teaches us, by its mysterious contact with the outer world, the infinite order of the universe.

The danger from materialism is not, as we usually incline to think, corruption of morals by degradation of the soul. Too much use, for censure's sake, has been made, against this system, of the seeming ease with which its professors have convinced themselves that they cut up by the roots the very principles of morality and duty. History proves, by examples too infamous, that barbarism and license are the privilege of no philosophic sect. The real enemies of society always have been, and always will be, the ignorant and the fanatical, and it must be frankly owned that, if these exist within the pale of materialism, there are quite enough of them outside. The danger in the doctrine which reverses the natural relation of things, and asserts that spirit is a product of matter, when in truth matter is a product of spirit, this danger is of another kind; materialism is fatal to the development of the experimental sciences themselves. If, in such a case, the example of men of genius might be appealed to, how eloquent would be the testimony of the two greatest physicists of this age, Ampère and Faraday, both so earnestly convinced, so religiously possessed by the reality of the unseen world! But there are other arguments. "All that we see of the world," says Pascal, "is but an imperceptible scratch in the vast range of Nature." The claim of mere experimentalism is that it may sentence men to the fixed and stubborn contemplation of this scratch. What folly! All the history of the development of the sciences proves that important discoveries all proceed from a different feeling, which is that of a continuation of forces beyond the limits of observation, and of a harmony in relations, overruling the singularities and deformities of detached experiences. To hedge one's self within what can be computed, weighed, and demonstrated, to trust such evidence only, and bar one's self inside the prison of the senses, to hush or scorn the suggestions of the spirit, our only true light, because it is a spark of the flame that vivifies all—this is, deny it or not, the condition and the subject state of materialism. Only reason can conceive the fixity, the generality, and the universality of relations, and all *savants* admit that the destiny of science is to establish laws possessing these three characteristics; but to admit that is to confess by implication that partial, incoherent, imperfect, relative details must undergo a refining, a thorough conversion, in the alembic of the mind, whence they issue, with so new an aspect and meaning, that what before seemed most important becomes as mere an accessory as it is possible to be, and that which looked most ephemeral takes its place among eternal things.

The conception of atoms dates from the highest antiquity. Leucippus and Democritus, the masters of Epicurus, several centuries before the Christian era, taught that matter is composed of invisible but indestructible corpuscles, the number of which is as boundless as the vastness of the space in which they are diffused. These corpuscles are solid, endowed with shape and motion. The difference of their forms regulates the difference of their movements, and consequently of their characteristics. The conception of a principle guiding these diversities, that is, of an intelligence as the supreme cause of differentiation, is not less ancient. "All was chaotic," Anaxagoras of Clazomene said; "an intelligence intervened, and regulated all." Plato, after defining matter as an existence very hard to understand, an eternal place, never perishing, and furnishing a stage of whatever begins to be, not the subject of sense and yet perceptible, and of which we only catch glimpses as in a dream, tells us that the supreme ruler "took this mass which was whirling in unchecked and unguided movement, and made order come out of disorder." And this ordering grows real in conformity with ideas, the prototypes of things, whose totality makes the divine essence itself. The world's activities are reflections of God's thoughts. To these two fundamental notions, that of atomism and that of idealism, Aristotle added a third, that of dynamism. As he holds, indeterminate matter, in the highest degree of abstraction, is without attributes. If it tends always toward form and action, that is because it contains a principle of power, a force. Force is in Aristotle's view the principle of form. The latter relates to substance. We have here the whole ancient philosophy regarding the world. Modern philosophy has taught us nothing different. Atomism, strengthened and widened by Descartes, and borrowed from him by Newton, is identical at bottom with that held by the teachers of Epicurus. In the same way, Leibnitz's dynamism is only a revival of Aristotle's. And, just as Descartes and Leibnitz reproduce the old Greek masters, contemporary science renews Descartes and Leibnitz.

"But what!" it will be said; "always repeating, never inventing, must that be the fixed doom of metaphysics?" Not so; these renewals contain continuous growth toward perfection. The old truth has been preserved, in its original sense, but it has been constantly illuminated and made exact in the lapse of time by happy efforts of speculative genius. Greek atomism had an immense chasm which Descartes filled by the conception of ether, the most marvellous of modern creations. Aristotle's dynamism was vague, and Leibnitz gave it precision by showing that the type and the fountain of force is and can be nothing else than spirit. He lifted the conception of force to the conception of soul. And what has been done in our days? We have computed the motion, we have detected the action, of that subtle ether, we have proved the absolute imperishableness of force, we have shown by many instances the fundamental identity of the appetitive and elective powers of chemistry and crystallography with those which psychology reveals. Here is the future of science and of metaphysics. Both will henceforth follow in their development the very course they have held to since the first day; they have never, like Penelope, destroyed yesterday's work the day after. They have pursued the same end with continuous advance, that is, the conception of invisible principles, and of the ideal essence of things. This end will remain the ever unattained goal of their ambition. The farther we shall advance, the more clearly and convincingly will they persist in defining those primal forces and elementary activities half guessed at from the very dawn of thought. Never false to themselves, they will always, at whatever point in history we appeal to them, represent the human soul unchanging in its nature, its powers, and its hopes. Let them never muse over the mournful question whether the work of the past will not vanish at some time without leaving a trace. All of it will survive, and from this confidence those who strive to increase the sum of knowledge draw their courage and consolation.

The conceptions of matter now entertained agree not only with the boldest deductions of most splendid discoveries of contemporary science, as well as with the oldest truths and the most instinctive faiths of humanity, but also with those loftier convictions, more precious and as solid, which form our moral and religious inheritance, and the crowning prerogative of our nature. The most advanced science rejects none of the traditions and objects to none of the great and lasting sentiments of past ages. On the contrary, it fixes the stamp of certainty on truths hitherto lacking adequate proofs, and rescues from the attacks of skepticism all that it coveted as its prey. No proof of the soul's immortality is so strong as that we have drawn from the necessary simplicity and eternity of all the principles of force. Nothing bears witness so powerfully to the majestic reality of a God as the spectacle of those diversities, all harmonious, which rule the infinite range of forces, and bind in unity the ordered pulses of the world. It is enough to fix the truth that the moral greatness and the intellectual dignity of a nation must always be measured by the standard of the esteem and credit it accords to high metaphysical speculations, and chiefly to such as relate to the constitution of matter. Meditation on the constitution of matter is the best method of teaching us to know spirit, and to understand that every thing must be referred to it, because from it every thing flows.—*Revue des Deux Mondes.*

THE GREAT NEBULA IN ORION.

By R. A. PROCTOR, B. A.

DURING the first four months of the year, the constellation Orion is very favorably situated for observation in the evening. This magnificent asterism is more easily recognized than the Great Bear, Cassiopeia's Chair, or the fine festoon of stars which adorns the constellation Perseus. There is, indeed, a peculiarity about Orion which tends considerably to facilitate recognition. The other constellations named above gyrate round the pole in a manner which presents them to us in continually-varying positions. It is not so with Orion. Divided centrally by the equator, the mighty hunter continues twelve hours above and twelve hours below the horizon. His shoulders are visible somewhat more, his feet somewhat less, than twelve hours. When he is in the south, he is seen as a giant with upraised arms, erect, and having one knee bent, as if he were ascending a height. Before him, as if raised on his left arm, is a curve of small stars, forming the shield, or target of lion's skin, which he is represented as uprearing in the face of Taurus. When Orion is in the east, his figure is inclined backward; when he is setting, he seems to be bent forward, as if rushing down a height; but he is never seen in an inverted position, like the northern constellations.

And we may note, in passing, that the figure of Orion, as he sets, does not exactly correspond with the image presented in that fine passage in "Maud:"

> "I arose, and all by myself, in my own dark garden-ground,
> Listening now to the tide, in its broad-flung shipwrecking roar,
> Now to the scream of a maddened beach dragged down by the wave,
> Walked in a wintry wind, by a ghastly glimmer, and found
> The shining daffodil dead, and Orion low in his grave;"

and again, toward the end of the poem:

> ". . . . It fell on a time of year
> When the face of night is fair on the dewy downs,
> And the shining daffodil dies, and the charioteer
> And starry Gemini hang like glorious crowns
> Over Orion's grave low down in the west."

I would not, however, for one moment, be understood as finding fault with these passages of Tennyson's finest poem. Detached from the context, the image is undoubtedly faulty; but there is a correctness in the very incorrectness of the image, placed as it is in the mouth of one

> "Raging alone as his father raged in his mood;"

brooding evermore on his father's self-murder:

> "On a horror of shattered limbs . . . .
> Mangled, and flattened, and crushed."

Let us pass on, however, to the subject of our paper.

Beneath the three bright stars which form the belt of Orion are several small stars, ranged, when Orion is in the south, in a vertical direction. These form the sword of the giant. On a clear night it is easy to see that the middle star of the sword presents a peculiarity of appearance: it shines as through a diffused haze. In an opera-glass this phenomenon is yet more easily recognizable. A very small telescope exhibits the cause of the peculiarity, for it is at once seen that what seemed a star is, in reality, a mass of small stars intermixed with a diffused nebulosity.

It is very remarkable circumstance that Galileo, whose small telescope, directed to the clear skies of Italy, revealed so many interesting phenomena, failed to detect

> "That marvellous round of milky light
> Below Orion."

It would not, indeed, have been very remarkable if he had simply failed to notice this object. But he would seem to have directed his attention for some time especially to the region in the midst of which Orion's nebula is found. He says: "At first I meant to delineate the whole of this constellation; but, on account of the immense multitude of stars—being also hampered through want of leisure—I left the completion of this design till I should have another opportunity." He therefore directed his attention wholly to a space of about ten square degrees, between the belt and sword, in which space he counted no less than 400 stars. What is yet more remarkable, he mentions the fact that there are many small spots on the heavens shining with a light resembling that of the Milky-Way (*complures similis coloris areolæ sparsim per æthera subfulgeant*); and he even speaks of nebulæ of this sort in the head, and belt, and *sword* of Orion. He asserts, however, that, by means of his telescope, these nebulæ were distinctly resolved into stars—a circumstance which, as we shall see presently, renders his description wholly inapplicable to the great nebula. Yet the very star around which (in the naked-eye view) this nebula appears to cling, is figured in Galileo's drawing of the belt and sword of Orion!

It seems almost inconceivable that Galileo should have overlooked the nebula, assuming its appearance in his day to have resembled that which it has at present. And, as it appears to have been established that, if the nebula has changed at all during the past century, it has changed very slowly indeed, one can scarcely believe that in Galileo's time it should have presented a very different aspect. Is it possible that the view suggested by Humboldt is correct—that Galileo did not see the nebula because he did not *wish* to see it? "Galileo," says Humboldt, "was disinclined to admit or assume the existence of starless nebulæ." Long after the discovery of the great nebula in Andromeda—known as the "transcendently-beautiful queen of the nebulæ"—Galileo omitted all mention in his works of any but starry nebulæ. The last-named nebula was discovered in 1614 by Simon Marius, whose claims to the discovery of Jupiter's satellites had greatly angered Galileo, and had called forth a torrent of invective, in which the Protestant German was abused as a heretic by Galileo, little aware that he would himself, before long, incur the displeasure of the Church. If we could suppose that an unwillingness, either to confirm his rival's discovery of a starless nebula, or to acknowledge that he had himself fallen into an error on the subject of nebulæ, prevented Galileo from speaking about the great nebula in Orion, we should be compelled to form but a low opinion of his honesty. It happens too frequently that—

> "The man of science himself is fonder of glory, and vain—
> An eye well-practised in Nature, a spirit bounded and poor."

That Hevelius, the "star-cataloguer," should have failed to detect the Orion nebula is far less remarkable; for Hevelius objected to the use of telescopes in the work of cataloguing stars. He determined the position of each star by looking at the star through minute holes or pinnules, at the ends of a long rod attached to an instrument resembling the quadrant.

The actual discoverer of the great nebula was Huyghens, in 1656. The description he gives of the discovery is so animated and interesting that we shall translate it at length. He says:

"While I was observing the variable belts of Jupiter, a dark band across the centre of Mars, and some indistinct phenomena on his disk, I detected among the fixed stars an appearance resembling nothing which had ever been seen before, so far as I am aware. This phenomenon can only be seen with large telescopes such as I myself make use of. Astronomers reckon that there are three stars in the sword of Orion, which lie very close to each other. But, as I was looking, in the year 1656, through my 23-feet telescope, at the middle of the sword, I saw, in place of one star, no less than twelve stars, which, indeed, is no unusual occurrence with powerful telescopes. Three of these stars seemed to be almost in contact, and with these were four others which shone as through a haze, so that the space around shone much more brightly than the rest of the sky. And, as the heavens were serene and appeared very dark, there seemed to be a gap in this part, through which a view was disclosed of brighter heavens beyond. All this I have continued to see up to the present time" (the work in which these remarks appear, the "Systema Saturnium," was published in 1659), "so that this singular object, whatever it is, may be inferred to remain constantly in that part of the sky. I certainly have never seen any thing resembling it in any other of the fixed stars. For other objects once thought to be nebulous, and the Milky-Way itself, show no mistiness when looked at through telescopes, nor are they any thing but congeries of stars thickly clustered together."

Huyghens does not seem to have noticed that the space between the three stars he described as close together is perfectly free from nebulous light, insomuch that, if the nebula itself is rightly compared to a gap in the darker heavens, this spot resembles a gap within the nebula. And, indeed, it is not uninteresting to notice how comparatively inefficient was Huyghens's telescope, though it was nearly eight yards in focal length. A good achromatic telescope two feet long would reveal more than Huyghens was able to detect with his unwieldy instrument.

Dominic Cassini soon after discovered a fourth star near the three seen by Huyghens. The four form the celebrated *trapezium*, an object interesting to the possessors of moderately good telescopes, and which has also been a subject of close investigation by professed astronomers. Besides the four stars seen by Cassini, there have been found five minute stars within and around the trapezium. These tiny objects seem to shine with variable brilliancy ; for sometimes one will surpass the rest, while at others it will be almost invisible.

After Cassini's discovery, pictures were made of the great nebula by Picard, Le Gentil, and Messier. These present no features of special interest. It is as we approach the present time, and find the great nebula the centre of quite a little warfare among astronomers—now claimed as an ally by one party, now by their opponents—that we begin to attach an almost romantic interest to the investigation of this remarkable object.

In the year 1811, Sir W. Herschel announced that he had (as he supposed) detected changes in the Orion nebula. The announcement appeared in connection with a very remarkable theory respecting nebulæ generally—Herschel's celebrated hypothesis of the conversion of some nebulæ into stars. The astronomical world now heard for the first time of that self-luminous nebulous matter, distributed in a highly-attenuated form throughout the celestial regions, which Herschel looked upon as the material from which the stars have been originally formed. There is an allusion to this theory in those words of the Princess Ida :

> "There sinks the nebulous star we call the Sun,
> If that hypothesis of theirs be sound."

And in the teaching of "comely Psyche :"

> "This world was once a fluid haze of light,
> Till toward the centre set the starry tides,
> And eddied into suns that, wheeling, cast
> The planets."

Few theories have met with a stranger fate. Received respectfully at first on the authority of the great astronomer who propounded it—then in the zenith of his fame—the theory gradually found a place in nearly all astronomical works. But, in the words of a distinguished living astronomer, "The bold hypothesis did not receive that confirmation from the labors of subsequent inquirers which is so remarkable in the case of many of Herschel's other speculations." It came to pass at length that the theory was looked upon by nearly all English astronomers as wholly untenable. In Germany it was never abandoned, however, and a great modern discovery has suddenly brought it into general favor, and has in this, as in so many other instances, vindicated Herschel's claim to be looked upon as the most clear-sighted, as well as the boldest and most original, of astronomical theorizers.

Herschel had pointed out various circumstances which, in his opinion, justified a belief in the existence of a nebulous substance—fire-mist or star-mist, as it has been termed—throughout interstellar space. He had discovered and observed several thousand nebulæ, and he considered that among these he could detect traces of progressive development. Some nebulæ were, he supposed, comparatively *young;* they showed no signs of systematic aggregation or of central condensation. In some nebulæ he traced the approach toward the formation of subordinate centres of attraction; while in others, again, a single centre began to be noticeable. He showed the various steps by which aggregation of the former kind might be supposed to result in the formation of star-clusters, and condensation of the latter kind into the formation of conspicuous single stars.

But it was felt that the strongest part of Herschel's case lay in his reference to the great nebula of Orion. He pointed out that, among all the nebulæ which might be reasonably assumed to be star-systems, a certain proportionality had always been found to exist between the telescope which first detected a nebula and that which effected its resolution into stars. And this was what might be expected to happen with star-systems lying beyond our galactic system. But how different is this from what was seen in the case of the Orion nebula! Here is an object so brilliant as to be visible to the naked eye, and which is found, on examination, to cover a large region of the heavens. And yet the most powerful telescopes had failed to show the slightest symptom of resolution. Were we to believe that we saw here a system of suns so far off that no telescope could exhibit the separate existence of the component luminaries, and therefore (considering merely the observed extent of the nebula, which is undoubtedly but a faint indication of its real dimensions) so inconceivably enormous in extent that the star-system of which our sun is a member shrinks into nothingness in comparison? Surely it seemed far more reasonable to recognize in the Orion nebula but a portion of our galaxy—a portion very vast in extent, but far inferior to that "limitless ocean of universes" presented to us by the other view.

And when Sir W. Herschel was able, as he thought, to point to changes taking place within the Orion nebula, it seemed yet more improbable that the object was a star-system.

But now telescopes more powerful than those with which the elder Herschel had scanned the great nebula were directed to its examination. Sir John Herschel, following in his father's footsteps, applied himself to the diligent survey of the marvellous nebula with a reflecting telescope 18 inches in aperture. He presented the nebula to us as an object of which "the revelation of the 10-feet telescope was but the mere rudiment." Strange outlying wisps and streamers of light were seen, extending far out into space. Yet more strange seemed the internal constitution of the object. So strange, indeed, did the nebula appear, "so unlike what had hitherto been known of collections of stars," that Sir John Herschel considered the evidence afforded by its appearance as sufficient to warrant the conclusion of a non-stellar substance.

But this eminent astronomer obtained a yet better view of the great nebula when he transported to the Cape of Good Hope an instrument equal in power to that which he had applied to the northern heavens. In the clear skies of the Southern Hemisphere the nebula shines with a splendor far surpassing that which it has in northern climes. It is also seen far higher above the horizon. Thus the drawing which Sir J. Herschel was able to execute during his three years' residence at the Cape is among the best views of the great nebula that have ever been taken. But, even under these favorable circumstances, Sir John records that "the nebula, through his great reflector, showed not a symptom of resolution."

Then Lassell turned his powerful mirror, two feet in diameter, upon the unintelligible nebula. But, though he was able to execute a remarkable drawing of the object, he could discern no trace of stellar constitution.

In 1845 Lord Rosse interrogated the great nebula with his three-feet mirror. Marvellous were the complexity and splendor of the object revealed to him, but not the trace of a star could be seen.

The end was not yet, however. Encouraged by the success of the three-feet telescope, Lord Rosse commenced the construction of one four times as powerful. After long and persistent labors, and at a cost, it is said, of £30,000, the great Parsonstown reflector, with its wonderful six-feet speculum, was directed to the survey of the heavens. At Christmas, 1845, while the instrument was yet incomplete, and in unfavorable weather, the giant tube was turned toward the Orion nebula. Prof. Nichol was the first who saw the mysterious object as pictured by the great mirror. Although the observation was not successful so far as the resolution of the nebula was concerned, yet Nichol's graphic account of the telescope's performance is well worth reading:

"Strongly attracted in youth by the lofty conceptions of Herschel," he writes, "I may be apt to surround the incident I have to narrate with feelings in so far of a personal origin and interest; but, unless I greatly deceive myself, there are few who would view it otherwise than I. With an anxiety natural and profound, the scientific world watched the examination of Orion by the six-feet mirror; for the result had either to confirm Herschel's hypothesis in so far as human insight ever could confirm it, or unfold among the stellar groups a variety of constitution not indicated by those in the neighborhood of our galaxy. Although Lord Rosse warned me that the circumstances of the moment would not permit me to regard the decision then given as absolutely final, I went in breathless interest to the inspection. Not yet the veriest trace of a star! Unintelligible as ever, *there* the nebula lay; but how gorgeous its brighter parts! How countless those streamers branching from it on every side! How strange, especially that large horn on the north, rising in relief from the black skies like a vast cumulous cloud! It was thus still possible that the nebula was irresolvable by human art; and so doubt remained. *Why* the concurrence of every favorable condition is requisite for success in such inquiries may be readily comprehended. The object in view is to discern, *singly*, sparkling points, small as the point of a needle, and close as the particles of a handful of sand; so that it needs but the smallest unsteadiness in the air, or imperfection in the shape of the reflecting surface, to scatter the light of each point, to merge them into each other, and present them as one mass."

Before long, Lord Rosse, after regrinding the great mirror, obtained better views of the mysterious nebula. Even now, however, he could use but half the power of the telescope, yet at length the doubts of astronomers as to the resolvability of the nebula were removed. "We could plainly see," he wrote to Prof. Nichol, "that all about the trapezium was a mass of stars, the rest of the nebula also abounding with stars, and exhibiting the characteristics of resolvability strongly marked." These views were abundantly confirmed by subsequent observations with the great mirror.

It will surprise many to learn that even Lord Rosse's great reflector is surpassed in certain respects by some of the exquisite refractors now constructed by opticians. As a light-gatherer the mirror is, of course, unapproachable by refractors. Even if it were possible to construct an achromatic lens six feet in diameter, yet, to prevent flexure, a thickness would have to be given to the glass which would render it almost impervious to light, and therefore utterly useless. But refractors have a power of definition not possessed by large reflectors. With a refractor eight inches only in aperture, for instance, Mr. Dawes has obtained better views of the planets (and specially of Mars) than Lord Rosse's six-feet speculum would give under the most favorable circumstances. And, in like manner, the performance of Lord Rosse's telescope on the Orion nebula has been surpassed—so far as resolution into discrete stars is concerned—by the exquisite defining power of the noble refractor of Harvard College (U. S.). By means of this instrument, hundreds of stars have been counted within the confines of the once intractable nebula.

It seemed, therefore, that all doubt had vanished from the subject which had so long perplexed astronomers. "That was proved to be *real*," Nichol wrote, "which, with conceptions of space enlarged even as Herschel's, we deemed *incomprehensible*."

Yet, even at this stage of the inquiry, there were found minds bold enough to question whether a perfectly satisfactory solution of the great problem had really been attained. Nor is it difficult, I think, to point out strong reasons for such doubts. I shall content myself by naming one which has always appeared to me irresistible.

The Orion nebula as seen in powerful telescopes covers a large extent of the celestial sphere. According to the Padre Secchi, who observed it with the great Merz refractor of the observatory at Rome, the nebulous region covers a triangular space, the width of whose base is some eight times, while its height is more than ten times as great as the moon's apparent diameter—a space more than fifty times greater than that covered by the moon. Now, I do not say that it is inconceivable that an outlying star-system, so far off as to be irresolvable by any but the most powerful telescopes, should cover so large a space on the heavens. On the contrary, I do not believe that a galaxy resembling our own would be resolvable at all, unless it were so near as to appear much larger than the Orion nebula. I believe astronomers have been wholly mistaken in considering any of the nebulæ to be such systems as our own. There may be millions of such systems in space, but I am very certain no telescope we could make would suffice to resolve any of them. But, what I do consider inconceivable is, that a nebula extending so widely, and placed (as supposed) beyond our system, should yet appear to cling (as the Orion nebula undoubtedly does) around the fixed stars seen in the same field with it. So strongly marked is this characteristic, that Sir John Herschel (who failed, apparently, to see its meaning) mentions among others no less than four stars—one of which is the bright middle star of the belt—as "involved in *strong* nebulosity," while the intermediate nebulosity is only just traceable. The probability that this arrangement is accidental is so small as to be almost evanescent. However, as I have said, English astronomers, almost without a dissentient voice, accepted the resolution of the nebula as a proof that it represents a distant star-system resembling our own galactic system, but far surpassing it in magnitude.

The time came, however, when a new instrument, more telling even than the telescope, was to be directed upon the Orion nebula, and with very startling results. The spectroscope had revealed much respecting the constitution of the fixed stars. We had learned that they are suns resembling our own. It remained only to show that the Orion nebula consists of similar suns, in order to establish beyond all possibility of doubt the theories which had been so complacently accepted. A very different result rewarded the attempt, however. When Dr. Huggins turned his spectroscope toward the great nebula, he saw, in place of a spectrum resembling the sun's, *three bright lines only!* A spectrum of this sort indicates that the source of light is a *luminous gas*, so that, whatever the Orion nebula may be, it is most certainly *not* a congeries of suns resembling our own.

It would be unwise to theorize at present on a result so remarkable. Nor can we assert that Herschel's *speculations* have been confirmed, though his general reasoning has been abundantly justified. Astronomers have yet to do much before they can interpret the mysterious entity which adorns Orion's sword. On every side, however, observations are being made which give promise of the solution of this and kindred difficulties. We have seen the light of comets analyzed by the same powerful instrument; and we learn that the light from the tail and coma is similar in quality (so far as observation has yet extended) to that emitted from the Orion nebula. We see, therefore, that in our own solar system we have analogues of what has been revealed in external space. I would not, indeed, go so far as to assert that the Orion nebula is a nest of cometic systems; but I may safely allege that there is now not a particle of evidence that the nebula lies beyond our galaxy.

Nor need we doubt the accuracy of Lord Rosse's observations. More than a year before his death, indeed, he mentioned to Dr. Huggins that "the *matter* of the great nebula in Orion had not been resolved by his telescope. In some parts of the nebula he observed a large number of exceedingly minute *red* stars. These red stars, however, though apparently *connected* with the irresolvable blue material of the nebula, yet seemed to be distinct from it."

The whole subject seems to be as perplexing as any that has ever been submitted to astronomers. Time, however, will doubtless unravel the thread of the mystery. We may safely leave the inquiry in the hands of the able observers and physicists whose attention has been for a long time directed toward it. And we need only note, in conclusion, that in the Southern Hemisphere there exists an object equally mysterious—the great nebula round η Argus—which has yielded similar results when tested with the spectroscope. The examination of this mysterious nebula, associated with the most remarkable variable in the heavens—a star which at one time shines but as a fifth-magnitude star, and at another exceeds even the brilliant Canopus in splendor—may, for aught that is known, throw a new light on the constitution of the great Orion nebula.—*Fraser's Magazine.*

OLD CONTINENTS.

By Prof. A. C. RAMSAY,
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FOR many years the stratified formations in general were described in manuals of geology as of marine origin, with the exception perhaps of part of the Coal-measures, and more unequivocally of the Purbeck and Wealden beds, and the fresh-water strata of parts of the Eocene and Miocene series. Even now the Old Red

Sandstone, as distinct from the marine Devonian rocks, is only occasionally and hesitatingly allowed to have a fresh-water origin, in spite of the statement made by Mr. Godwin-Austen long ago, that it was deposited in lakes.

My present object is to prove that, in the British Islands, all the great formations of a red color, and which are partly of Palæozoic, and partly of Mesozoic or Secondary age, were deposited in large inland lakes, fresh or salt; and if this can be established, then there was a long continental epoch in this part of the world comparable to, and as important in a physical point of view as any of, the great continents of the present day.

The Upper Silurian rocks of Shropshire, Herefordshire, Monmouthshire, and South Wales, are succeeded immediately by the Old Red Sandstone series, and there is no unconformity between them.

The teeming life of the Upper Silurian seas, in what is now Wales and the adjoining counties, continued in full force right up to the narrow belt of passage-beds which marks the change from Silurian brown muddy sands into lower Old Red Sandstone. In these transition beds on the contrary, genera, species, and often individuals, are few in number and sometimes dwarfed in size, the marine life rapidly dwindles away, and in the very uppermost Silurian beds land-plants appear, consisting of small pieces of undetermined twigs and the spore-cases of Lycopodiaceæ (*Pachytheca spherica*). Above this horizon the strata become red.

The poverty in number and the frequent small size of the shells in the passage-beds indicate a change of conditions in the nature of the waters in which they lived; and the plants alluded to clearly point to the close neighborhood of a land, of which we have no direct signs, in the vast development of a purely marine fauna in lower portions of the Ludlow strata. In the Ludlow bone-beds the fish-remains, *Onchus* and *Sphagodus*, and the large numbers of marine Crustacea, almost entirely trilobitic in the Ludlow rocks, indicate a set of conditions very unlike those that prevailed when the passage-beds and the lower strata of the true Old Red Sandstone were deposited, in both of which new fish appear, trilobites are altogether absent, and are more or less replaced by Crustacea of the genera *Pterygotus* and *Eurypterus*, one of which, *Eurypterus Symondsii*, has only been found in the lower Old Red Sandstone. Neither are there any mollusca in the Old Red Sandstone, excepting where that formation passes at the top into the Carboniferous rocks. All these circumstances indicate changes of conditions which were, I believe, of a geographical kind, and connected with the appearance in the area of fresh water.

The circumstances which marked the passage of the uppermost Silurian rocks into Old Red Sandstone seem to me to have been the following: First, a shallowing of the sea, followed by a gradual alteration in the physical geography of the district, so that the area became changed into a series of mingled fresh and brackish lagoons, which finally, by continued terrestrial changes, were converted into a great fresh-water lake, or, if we take the whole of Britain and areas now sea-covered beyond, into a series of lakes. The occurrence of a few genera or even species of fish and Crustacea common to the salt, brackish, or fresh waters, does not prove that the passage-beds and those still higher are truly marine. At the present day, animals commonly supposed to be essentially marine are occasionally found inhabiting fresh water. In the inland fresh lakes of Newfoundland, seals, which never visit the sea, are common and breed freely. The same is the case in Lake Baikal, 1,280 feet above the sea-level, in Central Asia; and, though these facts bear but slightly on my present subject, seals being air-breathing Mammalia, yet in the broad mouth of the Amazon, far above the tidal influx of sea-water, marine mollusca and other kinds of life are found, and in some of the lakes in Sweden there are marine Crustacea. This may be easily accounted for in the same way that I now attempt to account for analogous peculiarities in the Old Red Sandstone. These Swedish lakes were submerged during the Glacial period, and remained as deep basins while the land was emerging, and, after its final emergence, the salt-waters of the lakes freshened so slowly that some of the creatures inhabiting them had time by degrees to adjust themselves to new and abnormal conditions.

In further illustration of the subject let us suppose a set of circumstances such as the following: By long-continued upheaval of the mouth of the Baltic (a process now going on), its waters, already brackish in the Gulfs of Bothnia and Finland, would eventually become fresh, and true lacustrine strata over that area would succeed and blend into the marine and brackish water-beds of earlier date. Something of this kind I conceive to have marked the transition from the Upper Silurian beds into the Old Red Sandstone. Again: if by changes in the physical geography of the area, of a continental kind, a portion of the Silurian sea got isolated from the main ocean, more or less like the Caspian and the Black Sea, then the ordinary marine conditions of the "passage-beds," accompanied by some of the life of the period, might be maintained for what, in common language, seems to us a long time. There is geological proof that the Black Sea was once united to the Caspian, the two forming one great brackish lake. Since they were disunited and the Bosporus opened, the Black Sea has, it may be inferred, been steadily freshening; and it is easy to conceive that, by the reclosing of the Bosporus (a comparatively small geographical change), it might in the course of time again be converted into a fresh lake. At present a great body of salt-water is constantly being poured out through the Bosporus, and its place taken by the fresh waters of the Danube and other rivers, while, owing to the uncongenial quality of the freshening sea, some of the Black-Sea shells are strangely distorted, as was shown by Edward Forbes.

Or, if we take the Caspian alone as an example, there we have a brackish inland sea which was once joined to the ocean, as proved by its molluscan fauna. Changes in physical geography have taken place of such a kind that the Caspian is now separated from the ocean, while its waters, gradually growing salter by evaporation, are still inhabited by a poor and dwarfed marine molluscan fauna. If by increase of rainfall the Caspian became freshened, evaporation not being equal to the supply of water poured in by rivers, it would by-and-by, after reaching the point of overflow, be converted into a great fresh-water lake larger in extent than the whole area of Great Britain. Under these circumstances, in the Caspian area we should have a passage more or less gradual from marine to fresh-water conditions, such as I conceive to have marked the advent of the Old Red Sandstone.

The total absence of marine shells, and the nature of the fossil fishes of the Old Red Sandstone, also help to prove its fresh-water origin, for we find the nearest living analogues of the fishes in the Polypterus of the rivers of Africa, the Ceratodus of Australia, and in less degree in the Lepidosteus of North America. In the upper beds of the formation there is distinct proof of fresh water, in shells of the genus Anodonta mingled with ferns and other land-plants.

One other sign of the *inland* character of these waters remains to be mentioned—I mean the red color of their strata. As a general rule, all the great ocean formations, such as the Silurian, Carboniferous Limestone and Jurassic series, are gray, blue, brown, yellow, or of some such color. The marls and sandstones of the Old Red series are red because each grain of sand or mud is incrusted with a thin pellicle of peroxide of iron. When this coloring-matter is discharged the rock becomes white, and the iron that induces the strong red color in the New Red Marl, which much resembles that of the Old Red series, is found to be under two per cent. of the whole. I cannot conceive how peroxide of iron could have been deposited from solution in a wide and deep sea by any possible process, but, if carbonate of iron were carried in solution into lakes, it might have been deposited as a peroxide through the oxidizing action of the air and the escape of the carbonic acid that held it in solution. It is well known that ferruginous mud and ores of iron are deposited in the lakes of Sweden at the present day. These are periodically dredged for economic purposes by the proprietors till the layer is exhausted, and after a sufficient interval they renew their dredging operations and new deposits are found. With a difference the case is somewhat analogous to the deposition of peroxide of iron that took place in the Old Red Sandstone waters. It is obvious that common pink mud might have been formed from the mechanical waste of red granite, gneiss, or other red rocks in which pink felspars are found, but such felspars are tinted all through with the coloring-matter, and such a tint is very different from the deep-red color that was produced by the encasing of each individual grain of sediment with a thin pellicle of peroxide of iron.

The proof that the Old Red Sandstone was deposited in inland lakes is strengthened by a similar case in well-known ancient inland sheets of water, as shown by the red marls of the Miocene lakes of Central France.

It is known that in Ireland and in Scotland the Old Red Sandstone consists of two divisions, upper and lower, the upper division lying quite unconformably on the lower. In South Wales there are symptoms of the same kind of unconformity, for the upper beds of the Old Red Sandstone gradually overlap the lower strata. But, on consideration, this last circumstance does not appear to present any real difficulty with regard to the physical conditions of the period. If the great hollow in which the Dead Sea lies were gradually to get filled with fresh water and silted up, 1,300 feet of strata might be added above the level of the present surface of the water, without taking into account the depth of the sea and the deposits that have already been formed; and the upper strata all round would overlap the lower, apparently much as the Old Red Sandstone strata do in Wales and the adjoining counties. If the Caspian and other parts of the Asiatic area of inland drainage got filled with water, the same general results would follow.

Neither does the decided unconformity between the Upper and Lower Old Red Sandstones both in Ireland and in Scotland present any insuperable difficulty as to the fresh-water origin of the strata. It indicates only great disturbance and denudation, and a long lapse of geological time unrepresented by strata between the disturbance and denudation of the older beds and the deposition of the newer. Here also we have a parallel case in times comparatively recent, for the fresh-water Miocene strata of Switzerland and the adjacent countries have been exceedingly disturbed, heaved up into mountains, and subjected to great denudation, while at a much later geological date—that of to-day—we have all the large fresh-water lakes that diversify the country north of the Alps in the same general area.

It is unnecessary to dilate on the well-known continental aspect of a large part of the Carboniferous strata which succeed the Old Red Sandstone, especially of the Coal-measures, which in the north of England and in Scotland are not confined to the upper parts of the series, but reach down among strata which elsewhere are only represented by the marine beds of the Carboniferous Limestone. The soils (underclays), forests, and peat-mosses of the period, now beds of coal; the sun-cracks, rain-pittings, bones, and footprints of Labyrinthodont Amphibia on mud now hardened into shale; the estuarine and fresh-water shells—all point to vast marshes and great deltoid deposits, formed in a country which underwent many changes in its physical geography, and yet retained its identity throughout.

I will now discuss the conditions under which the British Permian strata were deposited. These rocks in their general characters very much resemble the Rothliegende, Kupferschiefer or Marl-slate, and Zechstein of the Thuringerwald and other parts of Germany, with this difference, that where the English Magnesian Limestone (Zechstein) is in force between Tynemouth and Nottingham, there are no red sandstones, marls, and conglomerates (Rothliegende), between the limestone and the Coal-measures, and in all the other parts of Britain where the red sandstones, etc., occur, there is only in two instances a little magnesian limestone lying, not at the top, but in the midst of, or interstratified with, the sandy and marly series.

The Permian marls, sandstones, conglomerates, and subangular breccias of Warwickshire, Staffordshire, Shropshire, Lancashire, North Wales, the Vale of Eden, and the south of Scotland, are all red, and, in fact, I nowhere recollect any important gray, yellow, or brown shales and sandstones among them. It is, however, foreign to my present purpose to discuss minor stratigraphical details, or any questions connected with English and Continental equivalent geological horizons of Permian age, nor is it necessary to do more than allude to the disturbances and denudations which preceded the unconformable deposition of our Permian strata, on all or any of the Palæozoic formations of earlier date. It is enough if I am able to show good reason for my belief that *all* of our Permian strata were deposited, not in the sea, but in the inland waters of lakes, which were probably mostly salt, but may possibly sometimes have been fresh or brackish.

As with the red strata of the Old Red Sandstone, so I consider that the red coloring-matter of the Permian sandstones and marls is due to the precipitation of peroxide of iron in a lake or lakes, in the manner already stated, and the nearly total absence of sea-shells, in by far the largest part of the areas occupied by the strata colored red, strongly points to this conclusion. There is other evidence bearing upon the question. The British plants of Permian age were mostly of genera common in the Coal-measures, though of different species. Among them there are *Calamites* and *Lepidodendron*, *Walchia*, *Chondrites*, *Ullmania*, *Cardiocarpon*, *Alethopteris*, *Sphenopteris*, *Neuropteris*, and many fragments of undetermined coniferous wood. This, however, forms no perfectly conclusive proof of the lacustrine origin of the strata, though it is not unlikely that land-plants, drifted by rivers, should have been water-logged and buried in the sediments of lakes.

The evidence derived from Reptilian remains more strongly points in the same direction. First we have the Labyrinthodont Amphibian, *Dasyceps Bucklandi*, from the Permian sandstones near Kenilworth; next the footprints mentioned by Prof. Harkness in the red sandstones of the Vale of Eden; and again, the numerous footprints in the sandstones of Corncockle Moor, in Dumfriesshire, long ago described by Sir William Jardine. All of these prints indicate that the Amphibia were accustomed to walk on damp surfaces of sand or mud open to the air, and the impressions left by their feet were afterward dried in the sun, before the waters flooded anew, overspread them with layers of sediment, in a manner that now annually takes place during the variations of the seasons on the broad flats of the Great Salt Lake of Utah and in other salt lakes. The occurrence of pseudomorphs of crystals of salt in the Permian beds of the Vale of Eden also helps to this conclusion, together with ripple-marks, sun-cracks, and rain-pittings, impressed on the beds. Crystals of common salt were not likely to have been deposited in an open sea, for, to form such crystals, concentration of chloride of sodium by evaporation is necessary. Deposits of gypsum, common in the Permian marls, could also only have been formed in inland waters by concentration, or on occasional surfaces of mud exposed to the sun and air, for no reasonable explanation can be offered of a process by means of which sulphate of lime can be deposited amid common mechanical sediments at the bottom of an open sea.

The question now arises how to account for the formation of the bands of magnesian limestone, sparingly intermingled with the red marls and sandstones of Lancashire and the Vale of Eden, and of that more important limestone district in the eastern half of the north of England, forming a long escarpment between Tynemouth and Nottingham. In these we have a true but restricted marine fauna, intermingled, however, with the relics of Amphibian and terrestrial life.

Let us broadly compare the marine life of the preceding epoch, that of the Carboniferous Limestone series, with the fossils of the Magnesian Limestone. The marine fauna of the Carboniferous Limestone of Britain contains about 1,500 species, most of which are mollusca (869), corals (124), echinodermata, crustacea (149), and fish (203). The Permian fauna feebly resembles that of the Carboniferous epoch, but, instead of the vast assemblage of many kinds of life found in the latter, the Magnesian Limestone of England only holds nine genera and 21 species of Brachiopoda, 16 genera and 31 species of Lamellibranchiata, 11 genera and 26 species of Gasteropoda, one Pteropod (*Theca*), and one Cephalopod (*Nautilus*). The whole comprises only 38 genera and 80 species, and all of these are dwarfed in size when compared with their Carboniferous congeners, when such there are.

I cannot easily account for this poverty of numbers and dwarfing of the forms, except on the hypothesis that the waters in which they lived were uncongenial to a true ocean fauna; and in this respect the general assemblage may be compared to the still more restricted marine faunas of the Caspian Sea and the Sea of Aral, or rather to that, a little more numerous and partly fossil, of the great Aralo-Caspian area of inland drainage, at a time when these inland brackish lakes formed part of a much larger body of water. Some of the fish of the Marl-slate have strong generic affinities with those of Carboniferous age, a number of which undoubtedly penetrated into the shallow estuarine lakes and salt lagoons of that period. Associated with the Permian mollusca we find the Labyrinthodont Amphibian *Lepidotosaurus Duffii*, together with *Proterosaurus Speneri* and *P. Huxleyi*, both of which were true Lacertilian land reptiles.

Besides the poverty of species and the small size of the Mollusca of the true Magnesian Limestone, the chemical composition of these strata seems to afford strong hints that they were formed in an inland salt lake, the sediments of which were partly deposited through the effect of solar evaporation. Broadly stated, the rock may be said to consist of a mixture of carbonate of lime and carbonate of magnesia in proportions more or less equal, mingled with a little silicious sand mechanically deposited. The solid dolomite still contains "about one-fifth per cent. of salts soluble in water, consisting of chlorides of sodium, magnesium, potassium, and calcium, and sulphate of lime. These must have been produced at the same time as the dolomite, and caught in some of the solution then present, which is thus indicated to have been of a briny character" (Sorby). But, instead of such deposits having been formed in open sea-water, I submit that this evidence, joined to the facts previously stated, leads me to believe that our Permian dolomite was formed in an inland salt lake, in which carbonates of lime and magnesia might have been deposited simultaneously. This deposition was chiefly the result of concentration of solutions caused by evaporation, the presence of carbonate of lime in the rock being partly due to organic agency, or the life and death of the molluscs that inhabit the waters. I cannot understand how deposits of carbonate of magnesia could have taken place in an open sea, where necessarily lime and magnesia only exist in solution in very small quantities in a vast bulk of water. In the open sea, indeed, the formation of all beds of limestone is produced simply by the secretion of carbonate of lime effected by molluscs, corals, and other organic agents, and I know of no animal that uses carbonate of magnesia to make its bones.

The very lithological character of some of the strata helps to lead to the same conclusion, for, when weathered, they are seen to consist of a number of thin layers curiously bent and convoluted, and approximately fitting into each other, like sheets of paper crumpled together, conveying the impression that they are somewhat tufaceous in character, or almost stalagmitic, if it be possible to suppose such deposits being formed under water. The curious concretionary and radiating structures common in the limestone are probably also connected with the chemical deposition of the sediments.

Arguments of the same kind apply to the magnesian limestones of Lancashire and the Vale of Eden, and the miserable marine fauna in some of these beds also indicates inland *unhealthy waters*, while the deposits of bedded gypsum so common in the marls of the series show that the latter could not have been deposited in the sea.

Taking all these circumstances into account, the poverty of the marine fauna, the terrestrial lizards, the Amphibia, and the land-plants, I cannot resist the conclusion that the Permian rocks of England were deposited in a lake or in a series of great inland continental lakes, brackish or salt; and, if this be true, it will equally apply to some other regions of Europe.

The strata that succeed the Permian formations in the geological scale are those included in the word Trias, on the continent of Europe. These consist of three subdivisions: first and lowest, the Bunter sandstone; second, the Muschelkalk; and third, the Keuper marl, or *Marnes irisées.* The Bunter sandstone on the Continent consists chiefly of red sandstones, with interstratified beds of red marl and thin bands of limestone, sometimes magnesian. These form the *Grès bigarré* of France. In these strata, near Strasbourg, about thirty species of land-plants are known, chiefly ferns, Calamites, Cycads, and Coniferæ, and with them remains of fish are found and Labyrinthodont Amphibia. In the same series there occur Lamellibranchiate marine mollusca of the genera Trigonia, Mya, Mytilus, and Posidonia, so few in number that they suggest the idea, not of the sea, but of an inland salt lake, especially when taken in connection with the Labyrinthodont Amphibia and the terrestrial plants.

The Muschelkalk, next in the series, is essentially marine. A partial submergence took place, and a large and varied fauna of Mesozoic type occupied the area previously covered by the lake deposits of the Bunter sandstone.

Above this comes the Keuper series, with Gypsum and dolomite, land-plants, fish, and Labyrinthodont remains, and a few genera and species of marine shells, again suggesting the idea of a set of conditions very different from those that prevailed when the Muschelkalk was formed.

These strata, as a whole, are the geological equivalents of the New Red Sandstone and Marl of England, with this difference—that the Muschelkalk is entirely absent in our country, and we only possess the New Red Sandstone (Bunter) and the New Red Marl (Keuper).

The kind of arguments already applied to part of the Permian strata may, with equal force, be used in relation to the New Red Sandstone and Marl of England. I have for long held that our New Red Sandstone was deposited in an inland lake, probably salt, and that our New Red Marl was certainly formed in a salt lake. Pseudo-morphous crystals of salt are common throughout the whole formation, which, besides, contains two great beds of rock-salt, each 80 or 100 feet thick, which could only have been deposited in a lake that had no outflow, and from which all the water poured into it by the rivers of the country was entirely got rid of by evaporation induced by solar heat. It has been proved by analyses that all spring and river waters contain chloride of sodium and other salts in solution, and in such a lake, by constant evaporation, salts must in time have become so concentrated that the water could hold no more in solution. This state of evaporation is now going on in the comparatively rainless areas of the Dead Sea, the Great Salt Lake of Utah, and in numerous lakes in Central Asia, though it is by no means asserted that in all of these positive deposition of salt has begun to take place. At length saline deposits began to be formed, which in the case of the New Red Marl consisted chiefly of common salt. This is impossible in an ordinary ocean, for the salt in solution cannot there be sufficiently concentrated to permit of deposition.

Gypsum and other salts contained in the red marl may also have been formed in like manner, and, as in the Permian and Old Red formations, I consider that the peroxide of iron which stains both salt and marl may have been carried into the lakes in solution as carbonate of iron, to be afterward deposited as a peroxide.

The remains of plants found in the British Keuper beds also speak of a surrounding land, while the Crocodile (*Stagonolepis*), the Dinosauria (land reptiles), Lizards (one of them a true land lizard, *Telerpeton*), and six supposed species of Labyrinthodont Amphibia, all tell the same tale of land. Rain-prints and sun-cracks are not wanting to help in the argument; and while the fishes yield no conclusive proof, the well-known bivalve crustacean *Estheria minuta* might have lived in any kind of area occupied by salt-water, while the small Marsupial Mammal *Microlestes antiquus* speaks conclusively of land.

Taken as a whole, it seems to me that the nearest conception we can form, of part of the old continent in which the Permian and New Red strata were deposited, is, that it physically resembled the great area of inland drainage of Central Asia, in which, from the Caspian 3,000 miles to the eastward, almost all the lakes are salt in a region comparatively rainless, and in which the area occupied by inland salt or brackish waters was formerly much more extensive than at present.

And now let me endeavor to sum up the whole of the argument. If, as I believe, the Old Red Sandstone was deposited in a lake or lakes; if the Coal-measures, as witnessed by the great river-beds, estuarine shoals, and wide-spread terrestrial vegetation, show proof of a continental origin; if the Permian strata were formed in inland salt or brackish waters, and if the New Red beds had a similar origin—then from the close of the Uppermost Silurian formation down to the influx of the Rhœtic Sea, which brought the Keuper Marl period to an end, there existed over the north of Europe, and in other lands besides, a great continent throughout all that time, one main feature of which was the abundance of Reptilian and Amphibian life. This old continent was probably comparable in extent to any of the largest continents of the present day, and perhaps comparable in the length of its duration to all the time represented by all the Mesozoic strata from the close of the Triassic epoch down to the latest strata of the

Chalk, and it may be even comprehending the additional time occupied in the formation of the Tertiary strata. But this latter part of the subject I propose to work out before long.

One other point remains. I have elsewhere attempted to prove, and the opinion is gaining ground in England, that this long continental epoch embraces at least two glacial episodes, as witnessed first by the bowlder-beds of the Old Red Sandstone of Scotland and the north of England, and secondly by the occurrence of similar deposits containing far-borne erratic blocks and ice-scratched stones, in a portion of that part of the Permian strata that is usually considered to represent the German Rothliegende. Should this be finally admitted, it may, on astronomical grounds, some day help us in the positive measurement of geological time.

Finally, let me rapidly pass in review what I think we know of later terrestrial, as opposed to marine epochs, in the British and neighboring areas of Europe. A wide-spred partial submergence brought the old continent to an end, and during the Liassic and Oolitic epoch (Jurassic) the Highlands of Scotland and other mountain-regions in the British Islands formed, with some other European Palæozoic rocks, groups of islands, round which, in warm seas, the Jurassic strata were deposited. These relics of an older continent, by deposition of newer strata and subsequent gradual upheaval, began to grow in extent, and at length formed the great continental area through which the mighty rivers flowed that deposited the strata of the Purbeck and Wealden series of England and the continent of Europe.

A larger submergence at length closed this broad local terrestrial epoch, and in those areas now occupied by Northern Europe (and much more besides), the sea, during the deposition of great part of the Chalk, attained a width and depth so great that probably only the tops of our British Palæozoic mountains stood above its level.

By subsequent elevation of the land, the fluvio-marine Eocene strata of Western Europe were formed, including in the term fluvio-marine the whole English series, embracing the London Clay, which as shown by its plant-remains was deposited at, or not far from, the mouth of a great river, which in size, and in the manner of the occurrence of some of these plants, may be compared to the Ganges. With this latter continent there came in from some land, unknown as yet, a great and new terrestrial mammalian fauna wonderfully different from that which preceded it in Mesozoic times, and from that day to this the greater part of Europe has been essentially a continent, and in a large sense all its terrestrial faunas have been of modern type.

One shadowy continent still remains unnamed, far older than the oldest of those previously spoken of. What and where was the land from which the thick and wide deposits that form the Silurian strata of Europe were derived? For all sedimentary strata, however thick and extended in area, represent the degradation of an equal amount of older rocks wherewith to form them. Probably, like the American Laurentian rocks, that old land lay in the north, but whether or not, of this at all events I have more than a suspicion, that the red, so-called Cambrian, beds at the base of the Lower Silurian series indicate the last relics of the fresh waters of that lost continent, sparingly interstratified with gray marine beds, in which a few trilobites and other sea-forms have been found. Going back in time beyond this, all reasoning or detailed geological history becomes vague in the extreme. The faunas of the Cambrian, and especially of the Lower Silurian rocks, from their abundance and variety show that they are far removed from the beginning of life. Looking to the vanishing point in the past and the unknown future, well might Hutton declare that in all that the known rocks tell us "we find no vestige of a beginning —no trace of an end."—*Contemporary Review.*

MAGNETO-ELECTRIC ILLUMINATION.

By WILLIAM CROOKES, F. R. S.

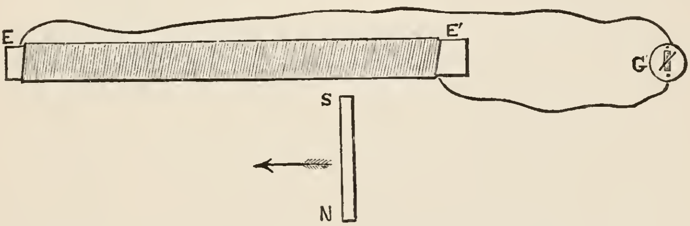
THE progress made in electric illumination during its advance toward perfection has been several times recorded in the pages of this journal. In our first number, published nearly ten years ago, Dr. J. H. Gladstone gave a history of the early difficulties attending the introduction of the magneto-electric machine as a light-generator for light-house illumination. Two years subsequently, the present writer described Wilde's magneto-electric machine, and, after a further lapse of years, during which time no very important improvement in the industrial application of magneto-electricity has been recorded, another step in advance has been made which calls for detailed notice.

The chief difficulties in the employment of magneto-electric currents for industrial purposes have been their almost instantaneous character and the rapid alternation in their direction. The instrumental means necessary to seize hold of these rapidly-alternating waves, and convert them into a more or less continuous stream of force flowing in one direction, are necessarily of a delicate character, and are easily put out of adjustment. This is easily understood when it is remembered that, in the machine first tried by Mr. Holmes, the rubbing surfaces were worn away in ten or twenty minutes. The Berlioz machine required for its maximum of intensity 350 or 400 revolutions per minute, and the direction of the current is then reversed nearly 6,000 times per minute; here, however, the alternate currents are not brought into one. In the machine made by Mr. Wilde for the Commissioners of Northern Light-houses, the first armature is made to revolve about 2,500 times a minute, generating 5,000 waves of electricity. These alternate currents are converted into an intermittent current moving in one direction only by means of a commutator. The second armature revolves 1,800 times a minute, generating 3,600 alternately-opposed waves of electric force, which are picked up and sent in one direction by a commutator, as in the former case.

It is evident that when a good friction contact is to be kept between pieces of metal moving at these enormous velocities, the wear and tear is very great. For a long time, however, it was thought that these difficulties were inherent to the magneto-electric machine, until electricians found, first, that the almost instantaneous flash of the current could be considerably lengthened out, and then that the successive waves generated could be so produced as to flow in the same instead of in opposite directions.

These important desiderata are supplied in a magneto-electric machine of a novel form, invented by M. Gramme. The principle is not difficult to understand. Take a long bar of soft iron, E, E′, Fig. 1,

Fig. 1.

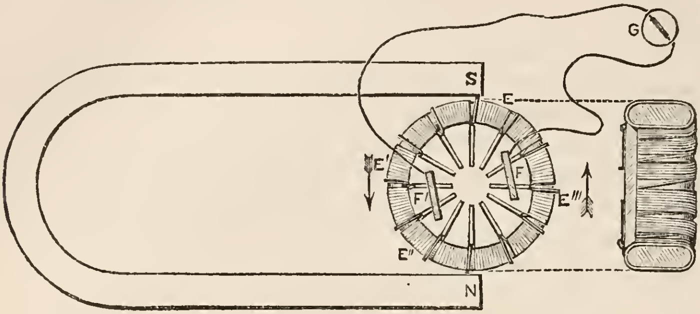


round which is coiled an insulated copper wire; to this bar, forming an electro-magnet, let a permanent magnet, S N, be presented, the south pole being nearest to the iron bar. Now move the permanent magnet in the direction of the arrow parallel with itself, with a uniform velocity, and always maintaining the same distance from the bar. The south pole of the permanent magnet will produce a north magnetic pole in the portion of the iron bar nearest to it; and the gradual displacement of this pole from one end to the other of the iron bar, caused by the motion of the magnet, will induce in the surrounding wire an electric current which may be rendered evident by the galvanometer, G. This current will not be instantaneous: it will continue to flow during the whole time the magnet is moving between the two ends, E E′, of the iron bar, and its time of duration may therefore be varied at pleasure.

This experiment shows that it may be possible, by proper arrangements, to realize a machine which will furnish a continuous current of electricity for as long as may be desired. We have only to imagine the electro-magnet, instead of being the straight bar shown in Fig. 1, bent into a circular form as at E, E′, E″, E‴, Fig. 2.

Submit this annular electro-magnet simultaneously to the influence of the two poles of the permanent horseshoe magnet, N S, and at the same time imagine it to revolve on its axis in the direction shown by the arrows.

FIG. 2.



The south pole, S, of the horseshoe magnet, will produce in that portion of the ring, E, which is near it, an electric current in a particular direction, as may be inferred from what we have said respecting the straight bar, Fig. 1. But the north pole, N, of the magnet, will likewise produce in the part of the ring which is in its neighborhood, E'', an electric current flowing in the opposite direction; and it is easily conceived that, in the two portions of the ring, E', and E''', which are in what may be called the mean position, there is no current at all. If, therefore, we wish to collect the two contrary currents produced simultaneously in the wire surrounding the electro-magnet, we have only to connect the wires at the mean position to two conductors by friction-contacts, F F', when the current can be carried away to a galvanometer, G, and rendered sensible.

The principle of the arrangement being thus understood, the construction of the machine itself will be readily intelligible.

It consists of a permanent horseshoe magnet, S, O, N, Fig. 3, between the poles of which revolves an electro-magnet. This electro-magnet consists of a ring of soft iron, round which is wound an insulated conducting wire, presenting no solution of continuity. It may be conceived as being an ordinary straight electro-magnet bent round in a circle, and the two ends of the conducting wire soldered together to establish continuity.

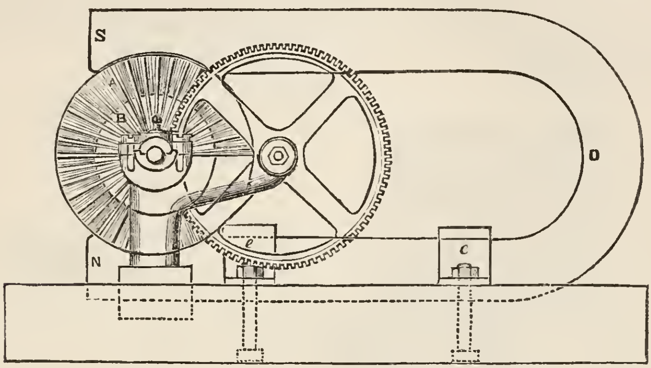
In Figs. 4 and 7 the electro-magnet is represented at A in section, while in Figs. 3 and 5 it is shown at A with the covering wire on it. It revolves round its axis on an axle to which movement is communicated either by means of belting, or with toothed gearing, shown in Figs. 3 and 4, worked by a handle, M.

The current is generated and collected in the following way: The wire surrounding the electro-magnet is, as we have said, continuous, but it is disposed in 40 sections or elements, each consisting, say, of

100 turns. The outer end of the coil of one section forms the commencement of the first coil of the next section, and so on. The whole of the wire is therefore divided into 40 equal sections, being, however, continuous throughout.

To understand better how an uninterrupted current is produced, let us imagine a line to be drawn equatorially, or perpendicular to the lines of force between the poles of the horseshoe magnet, and dividing the ring armature into two parts; suppose, likewise, that to the two ends of one of the 40 coils two wires are soldered, the other ends of which are attached to a galvanometer. Now let the ring be intermittently revolved in one direction, so as to give to the said coil a succes-

FIG. 3.



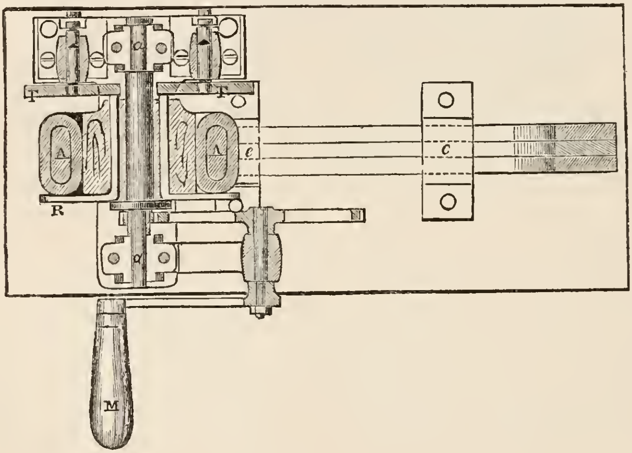
sion of movements of about 10 degrees, stopping each time to permit the galvanometer-needle to resume its normal position. It will then be seen that the whole time the coil is above the equatorial line the galvanometer-needle will be urged in the same direction, and the currents may be called *positive.* But, as soon as the said coil crosses the equatorial position, the currents generated in it will be *negative*, and in the opposite direction to what they were at the other half of the circle. This experiment shows that a reversal of the direction of movement carries with it a reversal of the direction of the current.

From this insight into what is produced in one of the sections, the general phenomena produced by the whole circle of coils are easily understood. The 20 sections which are on one side of the equatorial position are the source of positive currents; these may be of unequal intensity among themselves, but, for a uniform velocity of rotation, their sum is evidently constant; for, as one coil crosses the equatorial line from north to south, an opposite one comes up from south to north to take its place. On the other hand, the 20 sections which are on the other side of the equatorial line are the seat of negative currents, the sum of whose intensities is likewise constant, and equal to that of the positive currents.

Thus the revolving armature presents two groups of coils, generating two equal but opposite streams of electric force. The wire being unbroken, the currents neutralize each other, and there is no circulation. The result may be likened to what would be produced by taking two batteries, each of 20 cells, and connecting them in opposition by joining similar poles.

The problem now is to pick up these dormant currents and utilize their force. Its solution is apparent from the comparison we have just made. To collect the electric current from two batteries which are connected together in opposition, it is only necessary to fasten conducting wires to the two points of contact of similar poles, when the whole force of the batteries will flow along these wires. They were hitherto opposed, they now flow together, quantity-wise. M. Gramme, in the second portion of his invention, has adopted this artifice in an ingenious manner.

Fig. 4.



The various sections of the continuous electro-magnet are connected with radial pieces of copper shown at R in Figs. 3, 4, and 7, insulated one from the other, but coming very close. The termination of one coil of wire and the commencement of the adjacent coil are soldered to the same radial connector, of which, therefore, there are as many as there are coils. These radial connectors, on approaching the centre, are bent at right angles, as shown at R, Figs. 4 and 7, and pass through to the other side, where their ends form an inner concentric circle, being still insulated one from the other.

The friction-pieces F (Figs. 4, 5, and 6), consisting of disks of copper, are pressed, by means of springs shown at *r* (Figs. 5 and 6), against the circle formed by the extremities of the conducting radii R, at two points which are accurately in the equatorial line; that is to say, at the place where the equal and opposed currents generated in the upper and lower halves of the ring neutralize each other. Consequently the currents are collected and flow together along conducting wires, which are fastened to the friction-pieces F.

The perfect continuity of the current so obtained is secured by causing the friction-pieces F to touch simultaneously several of the radial conductors R; consequently the metallic circuit is never broken.

Fig. 5.

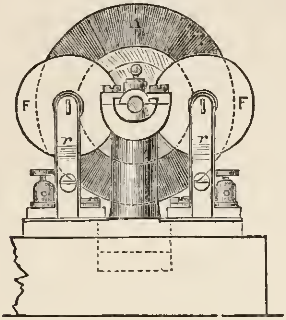
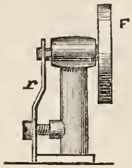
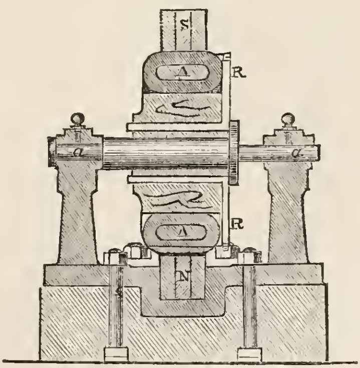


Fig. 6.



The effects produced by these machines vary with the rapidity of rotation. Experience shows that the electro-motive force is sensibly in proportion to the velocity; but it is probable that this force tends toward a limit, corresponding to a particular velocity, beyond which the electromotive force would remain constant, or even diminish. Moreover, the electromotive force is greater in proportion to the num-

Fig. 7.



ber of coils encircling the iron ring, but the relation between these two quantities has not yet been determined. The theoretical resistance of the machine should be one-fourth of the whole resistance of the wire wound round the ring armature; but the actual resistance is not so great, since each friction-disk always touches several radii, R, and the resistance of the coils thus embraced by the friction-disk has to be subtracted from the resistance of the circuit.

The possibility of augmenting the strength of the current by increasing the dimensions of the machine is too obvious to need more than a passing allusion. The effects may also be increased by connecting together several such machines, as galvanic piles are connected, either for intensity or quantity. The quality of the current likewise differs according to the kind of wire surrounding the armature, a short thick wire producing effects of quantity, and a long thin wire, of intensity. It is also easy to see that two horseshoe magnets, instead of one, may be made to act on one ring armature; that is to say, it may be actuated by four poles instead of two, or even by a greater number; always having a friction-disk between each pair of poles. Moreover, the permanent horseshoe magnet may be replaced by electro-magnets, which can be excited by a portion of the current derived from the machine itself, according to the now well-known method. At the beginning of rotation the residual magnetism of these electro-magnets will induce a feeble current in the ring; one-half of this passes round the electro-magnets, the four poles of which react on the armature. Of the four friction-pieces, two carry half the current to excite the electro-magnets, and the machine rapidly attains the maximum effect. From conducting wires attached to the other two friction-pieces a powerful current is available.

A machine of this kind, containing two horseshoe electro-magnets, one for exciting and the other for the exterior current, and having round each pole 7 kilos. of copper wire 3 m.m. diameter, when worked by hand, decomposes water, and fuses 26 centims. of iron wire 9-10ths m.m. in diameter. However slowly the armature is rotated, the needle of a large galvanometer having the wire only once round is deflected, and the effects increase in intensity as the velocity of rotation increases, up to a maximum of 700 or 800 turns a minute, a velocity which is easily obtained when steam is employed.

Such a machine, giving an absolute continuous current of electric force by the mere turning of a wheel, is of value outside the physical laboratory. It is available—(1) for medical purposes; (2) for telegraphy; (3) for electro-plating, gilding, etc.; (4) for military purposes, signalling, explosions, etc.; (5) for chemical decompositions; and (6) for electric illumination.

A large machine, which has lately been exhibited in London, driven by a 2½-horse-power engine, produced a light equal to 8,000 candles; a copper wire about 1¼ m.m. in thickness, suspended between the poles, became instantly red-hot with a revolution of little over 300 in a minute. Larger machines are being made that will probably give a light equal to 25,000 candles.

This machine has lately been examined by the French *Société d'Encouragement*, and, in accordance with the recommendation of the reporter, Count du Moncel, a prize of 3,000 francs has been awarded for it to M. Gramme; while the manager of the "Alliance Company," M. Joseph Van Malderen, who superintended its manufacture, has had awarded to him a gold medal. In his report, Count du Moncel says that a machine 1.25 metre in height, 0.8 metre long, and the same in width, driven by a 4-horse engine, gave a light equal to 900 carcel-lamps. It also heated to redness two juxtaposed copper wires 12 metres long and 0.7 m.m. diameter, and fused an iron wire 2.5 metres long and 1.3 m.m. thick.

The constancy of direction of the electric current generated by this machine is, however, not of so great an importance for the electric light as for other purposes for which it may be used. Indeed, the electric light is by many electricians thought to be superior when produced by a magneto-electric machine of the old form without any commutator. The alternate reversal of the currents of electricity produces no flickering or irregularity in the arc of light, as they occur far too quickly to be appreciated by the eye, while the rapid reversal of the direction causes the carbons to wear away with great regularity, thus enabling the point of light to be kept more easily in the focus.

For the electro-deposition of metals—copper, silver, etc.—constancy of direction of current is indispensable, and here the experiments show a marked superiority of the Gramme machine over other magneto-electric machines.

In the galvanoplastic works of M. Christofle, of Paris, where experiments have been going on for more than a year, it is found that the best machine hitherto known, when moved with a velocity of 2,400 revolutions per minute, only deposits 170 grammes of silver per hour; while a smaller Gramme machine moved with a velocity of 300 revolutions per minute deposits 200 grammes of silver per hour; the temperature of the annular armature not exceeding 50° C., with a velocity of 275 revolutions, no elevation of temperature is experienced. It will be easily comprehended how strongly this result, obtained with a speed of rotation eight times less than hitherto required, speaks in favor of M. Gramme's invention. Usually at M. Christofle's the circuits are arranged to deposit 600 grammes of silver per hour, and the manager of the factory finds that the deposition with this machine takes place with a regularity and constancy which leaves nothing to be desired, and which cannot be obtained by using any other source of electricity.

Recently, the electric light generated by a Gramme machine has been exhibited on the Victoria Tower of the Houses of Parliament. The machine is placed in the vaults of the House of Commons, near to the boilers, and is worked by a small engine, which was already there, and was convenient for the purpose. From the machine two copper wires, half an inch diameter, are led along the vaults to the base of the clock-tower, and thence upward to the signalling-point, a total length of nearly 900 feet, being about three times the distance that an electric current has ever before been conducted for a similar purpose. The signalling apparatus is placed in a lantern five feet high, four feet wide, and having a semicircular glazed front, which projects from the lantern of the belfry on the north side of the tower, or that overlooking the Victoria Embankment. It consists—first, of a fixed table, in which is inserted a flat brass ring 16 inches diameter and one inch broad, which serves as a roller-path for the apparatus carrying the lamp and reflector; next, there is a circular revolving table, having bearings on the roller-path, and which is moved around a central pivot projecting from the fixed table, being actuated by a worm wheel and screw. By means of this arrangement the light can be directed horizontally from side to side through an arc of 180°. It could, of course, be made to sweep the whole of the horizon, but the position of the lantern with regard to the clock-tower is such as to enable the light to be seen through the range of a semicircle only. Upon the revolving table, and hinged to it at the front, is the elevating table, which has a screw adjustment to the rear by which the light can be raised or depressed, being capable of vertical training through an arc of 25°. On the elevator is placed the lamp-table, upon which again is a sliding platform, on which the lamps themselves stand. There are two lamps, which are in use alternately, the carbon-points lasting but four hours, while the House frequently sits for ten.

The copper conductors terminate at the fixed part of the machine, and the method of carrying the current from them to the lamps is very ingenious, the moving parts of the apparatus forming in themselves conductors. The negative conductor is placed in metallic contact with one hinge of the elevator-table through the centre-pin on which the table revolves, and the positive conductor with the other hinge by means of the brass roller-path. The currents from those points are conducted to the lamp-table, and thence through the traversing platform to the lamps, metallic contact being obtained throughout the whole circuit by means of flat springs moving over flat surfaces. The changing of the lamps is effected, without any appreciable break of continuity in the light, by means of the traversing platform on which they stand, and which has a sliding motion from side to side. When the carbon-points in one lamp are nearly consumed, the traverser is quickly shifted from right to left, or *vice versa*, as may be necessary. The break of contact is but momentary, and only exists during the time required to move the traverser rapidly through a space of six inches. The light will not become extinct during that period, as there is not sufficient time to allow the incandescence of the carbon to entirely subside. The springs under the lamp thrown out of use are by this action removed from the metal plate in the lamp-table, and the springs under the fresh lamp are brought into contact, and the light is at once produced anew.

The intensifying apparatus at present in use is a holophole lent by

Messrs. Chance, and through which the rays are sent in parallel lines. It is 21 inches in diameter, and is composed of lenses, surrounded by annular prisms, the centre part refracting the rays and the outer rings reflecting them. Should the electric light be adopted, a special lens will be constructed, by means of which the rays will be diffused through an arc of 180°, instead of being sent in one direction only. The cost of this electric light is at present estimated at 10*d.* per hour.

It may be of interest if we consider some matters of scientific interest in connection with this machine. In the first place, it possesses an enormous advantage over the voltaic battery in the absolute constancy of the current so long as the velocity of rotation is uniform. In an experiment carried on for eight hours with one of the first machines constructed, the deviation of the needle of a galvanometer was absolutely invariable. Again, a voltaic battery is a complicated piece of apparatus; for each element consists of four separate solid pieces (the outer cell, the porous cell, the positive and the negative element) and two liquids, while in most experiments a considerable number of batteries is required. From this multiplicity of parts a voltaic battery is subject to many accidental derangements, which are likely to weaken if not destroy its power. With the magneto-electric machine there is no complication. All the parts are solidly connected together, and no special care is required.

It must also be remembered that a powerful voltaic battery costs almost as much when it is at rest as when in action. The magneto-electric machine, on the contrary, costs nothing when it is not producing an external current. This may be understood in two senses. It is, of course, evident that, when no current is required, the rotation of the machine may be stopped; but it is a remarkable fact that, even when rotation of the armature is still going on, no mechanical force is expended except that necessary to overcome friction, provided the exterior current does not flow. To understand this, let us examine a little more closely into the working of the machine. In the first place, suppose the machine to be in rapid movement, and furnishing a current in an exterior circuit, it will be observed that the armature does not get hot; from this it may be concluded that all the mechanical force transmitted to the machine is converted into electricity, since none is changed to heat. In the next place, the machine continuing to revolve with the same speed, suppose the exterior circuit to be broken; still the machine does not rise in temperature, showing that in this case there is neither production of heat nor electricity, and consequently no waste of mechanical force. From the way in which the currents in the armature are generated, when there is no exterior circuit along which they can flow, they neutralize one another, and keep in such perfect equilibrium that there is absolutely no circulation, and consequently no heating.

If the Gramme machine is set in motion by a force just sufficient to turn it with a definite velocity when the exterior current is flowing, and, if the outer circuit is suddenly broken, the machine is seen to acquire an increasing velocity, showing that the mechanical force applied to it, being no longer capable of going off as electricity, spends itself then in augmenting the velocity of the moving parts of the machine.

On the other hand, if the machine is kept at a certain speed of revolution while the outer circuit is broken, and the circuit is then suddenly closed, the speed instantly diminishes, showing that a portion of the force turning the machine changes into electricity.

These experiments show that, whether the machine be active or passive, there exists always a state of equilibrium between the expenditure of mechanical force and the production of electricity.—*Quarterly Journal of Science.*

THE STUDY OF SOCIOLOGY.

By HERBERT SPENCER.

XIV.—*Preparation in Biology.*

THE parable of the sower has its application to the progress of Science. Time after time new ideas are sown and do not germinate, or, having germinated, die for lack of fit environments, before they are at last sown under such conditions as to take root and flourish. Among other instances of this, one is supplied by the history of the truth here to be dwelt on—the dependence of Sociology on Biology. Even limiting the search to our own society, we may trace back this idea nearly three centuries. In the first book of Hooker's "Ecclesiastical Polity," it is enunciated as clearly as the state of knowledge in his age made possible—more clearly, indeed, than was to be expected in an age when science and scientific ways of thinking had advanced so little. Along with the general notion of natural law—along, too, with the admission that human actions, resulting as they do from desires guided by knowledge, also in a sense conform to law—there is a recognition of the fact that the formation of societies is determined by the attributes of individuals, and that the growth of a governmental organization follows from the natures of the men who have associated themselves the better to satisfy their needs. Entangled though this doctrine is with a theological doctrine, through the restraints of which it has to break, it is expressed with considerable clearness: there needs but better definition and further development to make it truly scientific.

Among reappearances of this thought in subsequent English writers, I will here name only one, which I happen to have observed in

"An Essay on the History of Civil Society," published a century ago by Dr. Adam Ferguson. In it the first part treats "Of the General Characteristics of Human Nature." Section I., pointing out the universality of the gregarious tendency, the dependence of this on certain affections and antagonisms, and the influences of memory, foresight, language, and communicativeness, alleges that "these facts must be admitted as the foundation of all our reasoning relative to man." Though the way in which social phenomena arise out of the phenomena of individual human nature is seen in but a general and vague way, yet it is seen—there is a conception of causal relation.

Before this conception could assume a definite form, it was necessary both that scientific knowledge should become more comprehensive and precise, and that the scientific spirit should be strengthened. To M. Comte, living when these conditions were fulfilled, is due the credit of having set forth with comparative definiteness the connection between the Science of Life and the Science of Society. He saw clearly that the facts presented by masses of associated men are facts of the same order as those presented by groups of gregarious creatures of inferior kinds; and that in the one case, as in the other, the individuals must be studied before the assemblages can be understood. He therefore placed Biology before Sociology in his classification of the sciences. Biological preparation for sociological study he regarded as needful, not only for the reason that the phenomena of corporate life, arising out of the phenomena of individual life, can be rightly coördinated only after the phenomena of individual life have been rightly coördinated, but also for the reason that the methods of inquiry which Biology uses are methods to be used by Sociology. In various ways, which it would take too much space here to specify, he exhibits this dependence very satisfactorily. It may, indeed, be contended that certain of his other beliefs prevented him from seeing all the implications of this dependence. When, for instance, he speaks of "the intellectual anarchy which is the main source of our moral anarchy"—when he thus discloses the faith pervading his "Course of Positive Philosophy," that true theory would bring right practice—it becomes clear that the relation between the attributes of citizens and the phenomena of societies is incorrectly seen by him: the relation is far too deep a one to be changed by mere change of ideas. Again, denying, as he did, the indefinite modifiability of species, he almost ignored one of the cardinal truths which Biology yields to Sociology—a truth without which sociological interpretations must go wrong. Though he admits a certain modifiability of Man, both emotionally and intellectually, yet the dogma of the fixity of species, to which he adhered, kept his conceptions of individual and social change within limits much too specific. Hence arose, among other erroneous preconceptions, this serious one, that the different forms of society, presented by savage and civilized races all over the globe, are but different stages in the evolution of one form: the truth being, rather, that social types, like types of individual organisms, do not form a series, but are classifiable only in divergent and redivergent groups. Nor did he arrive at that conception of the Social Science by which alone it becomes fully affiliated upon the simpler sciences—the conception of it as an account of the most complex forms of that continuous redistribution of matter and motion which is going on universally. Only when it is seen that the transformations passed through, during the growth, maturity, and decay of a society, conform to the same principles as do the transformations passed through by aggregates of all orders, inorganic and organic—only when it is seen that the process is in all cases similarly determined by forces, and is not scientifically interpreted until it is expressed in terms of those forces—only then is there reached the conception of Sociology as a science, in the complete meaning of the word.

Nevertheless, we must not overlook the greatness of the step made by M. Comte. His mode of contemplating the facts was truly philosophical. Containing, along with special views not to be admitted, many thoughts that are true as well as large and suggestive, the introductory chapters to his "Sociology" show a breadth and depth of conception beyond any previously reached. Apart from the tenability of his sociological doctrines, his way of conceiving social phenomena was much superior to all previous ways; and among other of its superiorities, was this recognition of the dependence of Sociology on Biology.

Here leaving the history of this idea, let us turn to the idea itself. There are two independent and equally-important ways in which these sciences are connected. In the first place, all social actions being determined by the actions of individuals, and all actions of individuals being vital actions that conform to the laws of life at large, a rational interpretation of all social actions implies knowledge of the laws of life. In the second place, a society as a whole, considered apart from its living units, presents phenomena of growth, structure, and function, like those of growth, structure, and function in an individual body; and these last are needful keys to the first. We will begin with this analogical connection.

Figures of speech, which very often mislead by conveying the notion of complete likeness where only distant analogy exists, occasionally mislead by making an actual correspondence seem a fancy. A metaphor, when used to express a real resemblance, raises a suspicion of mere imaginary resemblance, and so obscures the perception of intrinsic kinship. It is thus with the phrases "body politic," "political organization," and others, which tacitly liken a society to a living creature: they are assumed to be phrases having a certain convenience but expressing no fact—tending rather to foster a fiction.

And yet metaphors are here more than metaphors in the ordinary sense. They are devices of speech hit upon to suggest a truth at first dimly perceived, but which grows clearer the more carefully the evidence is examined. That there is a real analogy between an individual organism and a social organism becomes undeniable, when certain necessities determining structure are seen to govern them in common.

Mutual dependence of parts is that which initiates and guides organization of every kind. So long as, in a mass of living matter, all parts are alike, and all parts similarly live and grow without aid from one another, there is no organization: the undifferentiated aggregate of protoplasm thus characterized belongs to the lowest grade of living things. Without distinct faculties, and capable of but the feeblest movement, it cannot adjust itself to circumstances, and is at the mercy of environing destructive actions. The changes by which this structureless mass becomes a structured mass, having the characters and powers possessed by what we call an organism, are changes through which its parts lose their original likenesses, and do this while assuming the unlike kinds of activity for which their respective positions toward one another and surrounding things fit them. These differences of function, and consequent differences of structure, at first feebly marked, slight in degree, and few in kind, become, as organization progresses, definite and numerous; and in proportion as they do this the requirements are better met. Now, structural traits, expressible in the same language, distinguish lower and higher types of societies from one another; and distinguish the earlier stages of each society from the later. Primitive tribes show no established contrasts of parts. At first all men carry on the same kinds of activities, with no dependence on one another, or but occasional dependence. There is not even a settled chieftainship; and only in times of war is there a spontaneous and temporary subordination to those who show themselves the best leaders. From the small unformed social aggregates thus characterized, the progress is toward social aggregates of increased size, the parts of which acquire unlikenesses that become ever greater, more definite, and more multitudinous. The units of the society as it evolves fall into different orders of activities, determined by differences in their local conditions or their individual powers; and there slowly result permanent social structures, of which the primary ones become decided while they are being complicated by secondary ones, growing in their turns decided, and so on.

Even were this all, the analogy would be suggestive; but it is not all. These two metamorphoses have a cause in common. Beginning with an animal composed of like parts, severally living by and for themselves, on what condition only can there be established a change, such that one part comes to perform one kind of function, and another part another kind? Evidently each part can abandon that original state in which it fulfilled for itself all vital needs, and can assume a state in which it fulfils in excess some single vital need, only if its other vital needs are fulfilled for it by other parts that have meanwhile undertaken other special activities. One portion of a living aggregate cannot devote itself exclusively to the respiratory function, and cease to get nutriment for itself, unless other portions, that have become exclusively occupied in absorbing nutriment, give it a due supply. That is to say, there must be exchange of services. Organization in an individual creature is made possible only by dependence of each part on all, and of all on each. Now, this is obviously true also of social organization. A member of a primitive society cannot devote himself to an order of activity which satisfies one only of his personal wants, thus ceasing the activities required for satisfying his other personal wants, unless those, for whose benefit he carries on his special activity in excess, supply him with the benefits of their special activities. If he makes weapons instead of continuing a hunter, he must be supplied with the produce of the chase on condition that the hunters are supplied with his weapons. If he becomes a cultivator of the soil, no longer defending himself, then he must be defended by those who have become specialized defenders. That is to say, mutual dependence of parts is essential for the commencement and advance of social organization, as it is for the commencement and advance of individual organization.

Even were there no more to be pointed out, it would be clear enough that we are not here dealing with a figurative resemblance, but with a fundamental parallelism in principles of structure. We have but just begun to explore the analogy, however. The further we inquire, the closer we find it to be. For what, let us ask, is implied by mutual dependence—by exchange of services? There is implied some mode of communication between mutually-dependent parts. Parts that perform functions for one another's benefit must have appliances for conveying to one another the products of their respective functions, or for giving to one another the benefits (when these are not material products) which their respective functions achieve. And obviously, in proportion as the organization becomes high, the appliances for carrying on the intercourse must become involved. This we find to hold in both cases. In the lowest types of individual organisms, the exchange of services between the slightly-differentiated parts is effected in a slow, vague, inefficient way, by an irregular diffusion of the nutrient matters jointly elaborated, and by an irregular propagation of feeble stimuli, causing a rude coördination in the actions of the parts. It is thus, also, with small and simple social aggregates. No definite arrangements for interchanging services exist, but only indefinite ones. Barter of products—food, skins, weapons, or what not—takes place irregularly between individual producers and consumers throughout the whole social body: there is no trading or distributing system, as, in the rudimentary animal, there is no vascular system. So, too, the social organism of low type, like the individual organism of low type, has no appliances for combining the actions of its remoter parts. When coöperation of them against an enemy is called for, there is nothing but the spread of an alarm from man to man throughout the scattered population; just as, in an undeveloped kind of animal, there is merely a slow, undirected diffusion of stimulus from one point to all others. In either case, the evolution of a larger, more complex, more active organism, implies an increasingly-efficient set of agencies for conveying from part to part the material products of the respective parts, and an increasingly-efficient set of agencies for making the parts coöperate, so that the times and amounts of their activities may be kept in fit relations. And this is what we find. In the individual organism, as it advances to a high structure, no matter of what class, there arises an elaborate system of channels through which the common stock of nutritive matters (here added to by absorption, there changed by secretion, in this place purified by excretion, and in another modified by exchange of gases) is distributed throughout the body for the feeding of the various parts, severally occupied in their special actions; while in the social organism, as it advances to a high structure, no matter of what political type, there develops an extensive and complicated trading organization for the distribution of commodities, which, sending its heterogeneous currents through the kingdom by channels that end in retailers' shops, brings within reach of each citizen the necessaries and luxuries that have been produced by others, while he has been producing his commodity or small part of a commodity, or performing some other function or small part of a function, beneficial to the rest. Similarly, development of the individual organism, be its class what it may, is always accompanied by development of a nervous system which renders the combined actions of the parts prompt and duly proportioned, so making possible the adjustments required for meeting the varying contingencies; while along with development of the social organism there always goes development of directive centres, general and local, with established arrangements for interchanging information and instigation, serving to adjust the rates and kinds of activities going on in different parts.

Now, if there exists this fundamental kinship, there can be no rational apprehension of the truths of Sociology until there has been reached a rational apprehension of the truths of Biology. The services of the two sciences are, indeed, reciprocal. We have but to glance back at its progress, to see that Biology owes the cardinal idea, on which we have been dwelling, to Sociology; and that, having derived from Sociology this explanation of development, it gives it back to Sociology greatly increased in definiteness, enriched by multitudinous illustrations, and fit for extension in new directions. The luminous conception first enunciated by one whom we may claim as our countryman by blood, though French by birth, M. Milne-Edwards—the conception of "the physiological division of labor"—obviously originates from the generalization previously reached in Political Economy. Recognition of the advantages gained by a society when different groups of its members devote themselves to different industries, for which they acquire special aptitudes and surround themselves with special facilities, led to recognition of the advantages which an individual organism gains when parts of it, originally alike and having like activities, divide these activities among them; so that each, taking a special kind of activity, acquires a special fitness for it. But now note that, when carried from Sociology to Biology, this conception was forthwith greatly expanded. Instead of being limited to the functions included in nutrition, it was found applicable to all functions whatever. It turned out that the arrangements of the entire organism, and not of the viscera alone, conform to this fundamental principle—even the differences arising among the limbs, originally alike, were soon to be interpretable by it. And then mark that the idea, thus developed into an all-embracing truth in Biology, comes back to Sociology ready to be for it, too, an all-embracing truth. For it now becomes manifest that not to industrial arrangements only does the principle of the division of labor apply, but to social arrangements in general. The progress of organization, from that first step by which there arose a controlling chief, partially distinguished by his actions from those controlled, has been everywhere the same. Be it in the growth of a regulative class more or less marked off from classes regulated—be it in the partings of this regulative class into political, ecclesiastical, etc.—be it in those distinctions of duties within each class which are signified by gradations of rank—we may trace everywhere that fundamental law shown us by industrial organization. And, when we have once adequately grasped this truth which Biology borrows from Sociology and returns with vast interest, the aggregate of phenomena which a society at any moment presents, as well as the series of developmental changes through which it has risen to them, become suddenly illuminated, and the *rationale* comparatively clear.

After a recognition of this fundamental kinship there can be no difficulty in seeing how important, as an introduction to the study of social life, is a familiarization with the truths of individual life. For individual life, while showing us this division of labor, this exchange of services, in many and varied ways, shows it in ways easily traced; because the structures and functions are presented in directly-perceivable forms. And only when multitudinous biological examples have stamped on the mind the conception of a growing interdependence that goes along with a growing specialization, and have thus induced a habit of thought, will its sociological applications be duly appreciated.

Turn we now from the indirect influence which Biology exerts on Sociology, by supplying it with rational conceptions of social development and organization, to the direct influences it exerts by furnishing an adequate theory of the social unit—Man. For, while Biology is mediately connected with Sociology by a certain parallelism between the groups of phenomena they deal with, it is immediately connected with Sociology by having within its limits this creature whose properties originate social evolution. The human being is at once the terminal problem of Biology and the initial factor of Sociology.

If Man were uniform and unchangeable, so that those attributes of him which lead to social phenomena could be learned and dealt with as constant, it would not much concern the sociologist to make himself master of other biological truths than those cardinal ones above dwelt upon. But, since, in common with every other creature, Man is modifiable—since his modifications, like those of every other creature, are ultimately determined by surrounding conditions—and since surrounding conditions are in part constituted by social arrangements—it becomes requisite that the sociologist should acquaint himself with the laws of modification to which organized beings in general conform. Unless he does this he must continually err, both in thought and deed. As thinker, he will fail to understand the continual action and reaction of institutions and character, each slowly modifying the other through successive generations. As actor, his furtherance of this or that public policy, being unguided by a true theory of the effects wrought on citizens, will probably be mischievous rather than beneficial; since there are more ways of going wrong than of going right. How needful is enlightenment on this point will be seen, on remembering that scarcely anywhere is attention given to the modifications which a new agency, political or other, will produce in men's natures. Immediate influence on actions is alone contemplated, and the immeasurably more important influence on the bodies and minds of future generations is wholly ignored.

Yet the biological truths which should check this random political speculation and rash political action are conspicuous, and might, one would have thought, have been recognized by every one, even without special preparation in Biology. That faculties and powers of all orders, while they grow by exercise, dwindle when not used, and that alterations of nature descend to posterity, are facts continually thrust on men's attention, and more or less admitted by all. Though the evidence of heredity, when looked at in detail, seems obscure, because of the multitudinous differences of parents and of ancestors, which all take their varying shares in each new product, yet, when looked at in the mass, the evidence is overwhelming. Not to dwell on the countless proofs furnished by domesticated animals of many kinds as modified by breeders, the proofs furnished by the human races themselves are amply sufficient. That each variety of man goes on so reproducing itself that adjacent generations are nearly alike, however appreciable may sometimes be the divergence in a long series of generations, is undeniable. Chinese are recognizable as Chinese in whatever part of the globe we see them; every one assumes a black ancestry for any negro he meets; and no one doubts that the less-marked racial varieties have great degrees of persistence. On the other hand, it is unquestionable that the likenesses which the members of one human stock preserve, generation after generation, where the conditions of life remain constant, give place to unlikenesses that slowly increase in the course of centuries and thousands of years, if the members of that stock, spreading into different habitats, fall under different sets of conditions. If we assume the original unity of the human race, we have no alternative but to admit such divergences consequent on such causes; and, even if we do not assume this original unity, we have still, among the races classed by the community of their languages as Aryan, abundant proofs that the subjection to different modes of life produces, in course of ages, permanent bodily and mental differences: the Hindoo and the Englishman, the Greek and the Dutchman, have acquired undeniable contrasts of nature, physical and psychical, which can be ascribed to nothing but the continuous effects of circumstances, material, moral, social, on the activities, and therefore on the constitution. So that, as above said, one might have expected that biological training would scarcely be needed to impress men with these cardinal truths, all-important as elements in sociological conclusions.

As it is, however, we see that a deliberate study of Biology cannot be dispensed with. It is requisite that these scattered evidences, which but few citizens put together and think about, should be set before them in an orderly way; and that they should recognize in them the universal truths which living things at large exhibit. There requires a multiplicity of illustrations, many in their kinds, often repeated and dwelt upon. Only thus can there be produced an adequately-strong conviction that all organic beings are modifiable, that modifications are inheritable, and that therefore the remote issues of any new influence brought to bear on the members of a community must be serious.

To give a more definite and effective shape to this general inference, let me here comment on certain courses pursued by philanthropists and legislators, eager for immediate good results, but pursued without regard of these biological truths which, if borne in mind, would make them hesitate, if not desist.

Every species of creature goes on multiplying till it reaches the limit at which its mortality from all causes balances its fertility. Diminish its mortality, by removing or mitigating any one of these causes, and inevitably its numbers increase until mortality and fertility are again in equilibrium. However many injurious influences are taken away, the same thing holds, for the reason that the remaining injurious influences grow more intense. Either the pressure on the means of subsistence becomes greater; or some enemy of the species, multiplying in proportion to the abundance of its prey, becomes more destructive; or some disease, encouraged by greater proximity, becomes more prevalent. This general truth, everywhere exemplified among inferior races of beings, holds of the human race. True, it is in this case variously traversed and obscured. By emigration, the limits against which population continually presses are partially evaded; by improvements in production, they are continually removed further away; and, along with increase of knowledge, there comes an avoidance of detrimental agencies. Still, these are but qualifications of an inevitable action and reaction.

Let us here glance at the relation between this general truth and the legislative measures adopted to ward off certain causes of death. Every individual eventually dies from inability to withstand some environing action. It may be a mechanical force that cannot be resisted by the strengths of his bodily structures; it may be a deleterious gas which, absorbed into his blood, so deranges the processes throughout his body as finally to overthrow their balance; or it may be, and most frequently is, an absorption of his bodily heat by surrounding things that is too great for his enfeebled functions to meet. In all cases, however, it is one, or some, of the many forces to which he is exposed, and in presence of which his vital activities have to be carried on. He may succumb early or late, according to the goodness of his structure and the incidents of his career. But, in the natural working of things, those having imperfect structures succumb before they have offspring, leaving those with fitter structures to produce the next generation. And, obviously, the working of this process is such that as many will continue to live and to reproduce as can do so under the conditions then existing: if the assemblage of influences becomes more difficult to withstand, a larger number of the feebler disappear early; if the assemblage of influences is made more favorable, by the removal of, or mitigation of, some unfavorable influence, there is an increase in the number of the feebler who survive and leave posterity. Hence two proximate results, conspiring to the same ultimate result. First, population increases at a greater rate than it would otherwise have done: so subjecting all persons to certain other destroying agencies in more intense forms. Second, by intermarriage of the feebler who now survive, with the stronger who would otherwise have alone survived, the general constitution is brought down to the level of strength required to meet these more favorable conditions. That is to say, there by-and-by arises a state of things under which a general decrease in the power of withstanding this mitigated destroying cause, and a general increase in the activity of other destroying causes, consequent on greater numbers, bring mortality and fertility into the same relation as before—there is a somewhat larger number of a somewhat weaker race.

There are further ways in which this process necessarily works a like general effect, however far it is carried. For, as fast as more and more detrimental agencies are removed or mitigated, and as fast as there goes on an increasing survival and propagation of those having delicately-balanced constitutions, there arise new destructive agencies. Let the average vitality be diminished by more effectually guarding the weak against adverse conditions, and inevitably there come fresh diseases. A general constitution, previously able to bear without derangement certain variations in atmospheric conditions, and certain degrees of other unfavorable actions, if lowered in tone, will become subject to new kinds of perturbation, and new causes of death. In illustration I need but refer to the many diseases from which civilized races suffer, but which were not known to the uncivilized. Nor is it only by such new causes of death that the rate of mortality, when decreased in one direction, increases in another. The very precautions against death are themselves, in some measure, new causes of death. Every further appliance for meeting an evil, every additional expenditure of effort, every extra tax to meet the cost of supervision, becomes a fresh obstacle to living. For, always in a society where population is pressing on the means of subsistence, and where the efforts required to fulfil vital needs are so great that they here and there cause premature death, the powers of producers cannot be further strained by calling on them to support a new class of non-producers, without, in some cases, increasing the wear and tear to a fatal extent. And, in proportion as this policy is carried further—in proportion as the enfeeblement of constitution is made greater, the required precautions multiplied, and the cost of maintaining these precautions augmented—it must happen that the increasing physiological expenditure thrown on these enfeebled constitutions must make them succumb so much the earlier: the mortality evaded in one shape must come round in another.

The clearest conception of the state brought about will be gained, by supposing the society thus produced to consist of old people. Age differs from maturity and youth in being less able to withstand influences that tend to derange the functions, as well as less able to bear the efforts needed to get the food, clothing, and shelter, by which resistance to these influences may be carried on; and, where no aid is received from the younger, this decreased strength and increased liability to derangement by incident forces make the life of age difficult and wearisome. Those who, though young, have weak constitutions, are much in the same position: their liabilities to derangement are similarly multiplied, and, where they have to support themselves, they are similarly overtaxed by the effort, relatively great to them and made greater by the maintaining of precautions. A society of enfeebled people, then, must lead a life like that led by a society of people who had outlived the vigor of maturity, and yet had none to help them; and their life must also be like, in lacking that overflowing energy which, while it makes labors easy, makes enjoyments keen. In proportion as vigor declines, not only do the causes of pain multiply, while the tax on the energies becomes more trying, but the possibilities of pleasure decrease; many delights demanding, or accompanying, exertion are shut out; and others fail to raise the flagging spirits. So that, to sum up, lowering the average type of constitution to a level of strength *below that which meets without difficulty the ordinary strains, and perturbations, and dangers*, while it fails eventually to diminish the rate of mortality, makes life more a burden and less a gratification.

I am aware that this reasoning may be met by the criticism that, carried out rigorously, it would negative social ameliorations in general. Some, perhaps, will say that even those measures by which order is maintained might be opposed for the reason that there results from them a kind of men less capable of self-protection than would otherwise exist. And there will doubtless be suggested the corollary that no influences detrimental to health ought to be removed. I am not concerned to meet such criticisms, for the reason that I do not mean the conclusions above indicated to be taken without qualification. It is obvious enough that, up to a certain point, the removal of destructive causes leaves a balance of benefit. The simple fact, that, with a largely-augmented population, longevity is greater now than heretofore, goes far toward showing that, up to the time lived through by those who die in our day, there had been a decrease of the causes of mortality in some directions, greater than their increase in other directions. Though a considerable drawback may be suspected—though, on observing how few thoroughly-strong people we meet, and how prevalent are chronic ailments notwithstanding the care taken of health it may be inferred that bodily life now is lower in quality than it was, though greater in quantity—yet there has probably been gained a surplus of advantage. All I wish to show is, that there are limits to the good gained by a such a policy. It is supposed in the Legislature, and by the public at large, that, if, by measures taken, a certain number of deaths by disease have been prevented, so much pure benefit has been secured. But it is not so. In any case, there is a set-off from the benefit; and, if such measures are greatly multiplied, the deductions may eat up the benefit entirely, and leave an injury in its place. Where such measures ought to stop, is a question that may be left open. Here my purpose is simply to point out the way in which a far-reaching biological truth underlies rational conclusions in Sociology, and also to point out that formidable evils may arise from ignoring it.

Other evils, no less serious, are entailed by legislative actions and by actions of individuals, single and combined, which overlook or disregard a kindred biological truth. Besides an habitual neglect of the fact that the quality of a society is physically lowered by the artificial preservation of its feeblest members, there is an habitual neglect of the fact that the quality of a society is lowered morally and intellectually, by the artificial preservation of those who are least able to take care of themselves.

If any one denies that children bear likenesses to their progenitors in character and capacity—if he holds that men whose parents and grandparents were habitual criminals have tendencies as good as those of men whose parents and grandparents were industrious and upright—he may consistently hold that it matters not from what families in a society the successive generations descend. He may think it just as well if the most active, and capable, and prudent, and conscientious people die without issue, while many children are left by the reckless and dishonest. But, whoever does not espouse so insane a proposition, must admit that social arrangements which retard the multiplication of the mentally-best, and facilitate the multiplication of the mentally-worst, must be extremely injurious.

For, if the unworthy are helped to increase by shielding them from that mortality which their unworthiness would naturally entail, the effect is to produce, generation after generation, a greater unworthiness. From decreased use of self-conserving faculties already deficient, there must result, in posterity, the smaller amounts of self-conserving faculties. The general law which we traced above, in its bodily applications, may be traced here in its mental applications. Removal of certain difficulties and dangers, which have to be met by intelligence and activity, is followed by a diminished ability to meet difficulties and dangers. Among children born to the more capable who marry with the less capable, thus artificially preserved, there is not simply a lower average power of self-preservation than would else have existed, but the incapacity reaches in some a greater extreme. Smaller difficulties and dangers become fatal in proportion as greater ones are warded off. Nor is this the whole mischief. For such members of a population as do not take care of themselves, but are taken care of by the rest, inevitably bring on the rest extra exertion, either in supplying them with the necessaries of life, or in maintaining over them the required supervision, or in both. That is to say, in addition to self-conservation and the conservation of their own offspring, the best, having to undertake the conservation of the worst, and of their offspring, are subject to an overdraw upon their energies. In some cases this stops them from marrying; in other cases it diminishes the numbers of their children; in other cases it causes inadequate feeding of their children; in other cases it brings their children to orphanhood—in every way tending to arrest the increase of the best, to deteriorate their constitutions, and to pull them down toward the level of the worst.

Fostering the good-for-nothing at the expense of the good is an extreme cruelty. It is a deliberate storing-up of miseries for future generations. There is no greater curse to posterity than that of bequeathing them an increasing population of imbeciles and idlers and criminals. To aid the bad in multiplying, is, in effect, the same as maliciously providing for our descendants a multitude of enemies. It may be doubted whether the maudlin philanthropy which, looking only at immediate mitigations, persistently ignores remote results, does not inflict a greater total of misery than the extremest selfishness inflicts. Refusing to consider the remote influences of his incontinent generosity, the thoughtless giver stands but a degree above the drunkard who thinks only of to-day's pleasure and ignores to-morrow's pain, or the spendthrift who seeks immediate delights at the cost of ultimate poverty. In one respect, indeed, he is worse; since, while getting the present pleasure produced in giving pleasure, he leaves the future miseries to be borne by others—escaping them himself. And calling for still stronger reprobation is that scattering of money prompted by misinterpretation of the saying that "charity covers a multitude of sins." For, in the many whom this misinterpretation leads to believe that by large donations they can compound for evil deeds, we may trace an element of positive baseness—an effort to get a good place in another world, no matter at what injury to fellow-creatures.

How far the mentally-superior may, with a balance of benefit to society, shield the mentally-inferior from the evil results of their inferiority, is a question too involved to be here discussed at length. Doubtless it is in the order of things that parental affection, the regard of relatives, and the spontaneous sympathy of friends and even of strangers, should mitigate the pains which incapacity has to bear, and the penalties which unfit impulses bring round. Doubtless, in many cases the reactive influence of this sympathetic care which the better take of the worse, is morally beneficial, and in a degree compensates by good in one direction for evil in another. It may be fully admitted that individual altruism, left to itself, will work advantageously—wherever, at least, it does not go to the extent of helping the unworthy to multiply. But an unquestionable mischief is done by agencies which undertake in a wholesale way the preservation of good-for-nothings: putting a stop to that natural process of elimination by which otherwise society continually purifies itself. For not only by such agencies is this conservation of the worst and destruction of the best carried further than it would else be, but there is scarcely any of that compensating advantage which individual altruism implies. A mechanically-working State-apparatus, distributing money drawn from grumbling rate-payers, produces little or no moralizing effect on the capables to make up for multiplication of the incapables. Here, however, it is needless to dwell on the perplexing questions hence arising. My purpose is simply to show that a rational policy must recognize certain general truths of Biology, and to insist that only when study of these general truths, as illustrated throughout the living world, has woven them into the conceptions of things, is there gained an adequately-strong conviction that enormous mischief must result from ignoring them.[1]

Biological truths and their corollaries, presented under these special forms as bases for sociological conclusions, are introductory to a more general biological truth including them—a general biological truth which underlies all rational legislation. I refer to the truth that every species of organism, including the human, is always adapting itself, both directly and indirectly, to its conditions of existence.

The actions which have produced every variety of man—the actions which have established in the Negro and the Hindoo constitutions that thrive in climates fatal to Europeans, and in the Fuegian a constitution enabling him to bear without clothing an inclemency almost too great for other races well clothed—the actions which have developed in the Tartar races nomadic habits that are almost insurmountable, while they have given to North-American Indians desires and aptitudes which, fitting them for a hunting-life, make a civilized life intolerable—the actions doing this, are also ever at work moulding citizens into correspondence with their circumstances. While the bodily natures of citizens are being fitted to the physical influences and industrial activities of their locality, their mental natures are being fitted to the structure of the society they live in. Though, as we have seen, there is always an approximate fitness of the social unit to its social aggregate, yet the fitness can never be more than approximate, and readjustment is always going on. Could a society remain unchanged, something like a permanent equilibrium between the nature of the individual and the nature of the society would presently be reached. But the type of each society is continually being modified by two causes—by growth, and by the actions, warlike or other, of adjacent societies. Increase in the bulk of a society inevitably leads to change of structure; as also does any alteration in the ratio of the predatory to the industrial activities. Hence continual social metamorphosis, involving continual alteration of the conditions under which the citizen lives, produces in him an adaptation of character which, tending toward completeness, is ever made incomplete by further social metamorphosis.

While, however, each society, and each successive phase of each society, presents conditions more or less special, to which the natures of citizens adapt themselves, there are certain general conditions

[1] Probably most readers will conclude that in this, and in the preceding Section, I am simply carrying out the views of Mr. Darwin in their applications to the human race. Under the circumstances, perhaps, I shall be excused for pointing out that the same beliefs, otherwise expressed, are contained in Chapters XXV. and XXVIII. of "Social Statics," published in December, 1850.

which, in every society, must be fulfilled to a considerable extent before it can hold together; and which must be fulfilled completely before social life can be complete. Each citizen has to carry on his activities in such ways as not to impede other citizens in the carrying on of their activities more than he is impeded by them. That any citizen may so behave as not to deduct from the aggregate welfare, it is needful that he shall perform such function, or share of function, as is of value equivalent at least to what he consumes; and it is further needful that, both in discharging his function and in pursuing his pleasure, he shall leave others similarly free to discharge their functions and to pursue their pleasures. Obviously, a society formed of units who cannot live without mutual hindrance, is one in which the happiness is of smaller amount than it is in a society formed of units who can live without mutual hindrance. And obviously the sum of happiness in such a society is still less than that in a society of which the units voluntarily aid one another.

Now, under one of its leading aspects, civilization is a process of developing in citizens a nature capable of fulfilling these all-essential conditions; and, neglecting their superfluities, laws and the appliances for enforcing them are expressions and embodiments of these all-essential conditions. On the one hand, those severe systems of slavery, and serfdom, and punishment for vagabondage, which characterized the less-developed social types, stand for the necessity that the social unit shall be self-supporting. On the other hand, the punishments for murder, assault, theft, etc., and the penalties on breach of contract, stand for the necessity that, in the course of the activities by which he supports himself, the citizen shall neither directly injure other citizens, nor shall injure them indirectly, by taking or intercepting the returns their activities bring. And it needs no detail to show that a fundamental trait in social progress is an increase of industrial energy, leading citizens to support themselves without being coerced in the harsh ways once general; that another fundamental trait is the progressive establishment of such a nature in citizens that, while pursuing their respective ends, they injure and impede one another in smaller degrees; and that a concomitant trait is the growth of governmental restraints which more effectually check the remaining aggressiveness. That is to say, while the course of civilization shows us a clearer recognition and better enforcement of these essential conditions, it also shows us a gradual moulding of humanity into correspondence with them.

Along with the proofs thus furnished that the biological law of adaptation, holding of all other species, holds of the human species, and that the change of nature undergone by the human species since societies began to develop, has been an adaptation of it to the conditions implied by harmonious social life, we receive the lesson, that the one thing needful is a rigorous maintenance of these conditions. While all see that the immediate function of our chief social institutions is the securing of an orderly social life by maintaining these conditions, very few see that their further function, and in one sense more important function, is that of fitting men to fulfil these conditions spontaneously. The two functions are inseparable. From the biological laws we have been contemplating, it is, on the one hand, an inevitable corollary that, if these conditions are maintained, human nature will gradually adapt itself to them; while, on the other hand, it is an inevitable corollary that, by no other discipline than subjection to these conditions, can fitness to the social state be produced. Enforce these conditions, and adaptation to them will continue. Relax these conditions, and by so much there will be a cessation of the adaptive changes. Abolish these conditions, and, after the consequent social dissolution, there will commence (unless they are reëstablished) an adaptation to the conditions then resulting—those of savage life. These are conclusions from which there is no escape, if man is subject to the laws of life in common with living things in general.

It may, indeed, be rightly contended that, if those who are but little fitted to the social state are rigorously subjected to these conditions, evil will result; intolerable restraint, if it does not deform or destroy life, will be followed by violent reaction. We are taught by analogy, that greatly-changed conditions from which there is no escape fail to produce adaptation because they produce death. Men having constitutions fitted for one climate, cannot be fitted to an extremely-different climate by persistently living in it, because they do not survive, generation after generation. Such changes can be brought about only by slow spreadings of the race through intermediate regions having intermediate climates, to which successive generations are accustomed little by little. And doubtless the like holds mentally. The intellectual and emotional natures required for high civilization are not to be obtained by forcing on the completely-uncivilized the needful activities and restraints in unqualified forms: gradual decay and death, rather than adaptation, would result. But so long as a society's institutions are indigenous, no danger is to be apprehended from a too-strict maintenance of the conditions to the ideally-best social life; since there can exist neither the required appreciation of them nor the required appliances for enforcing them. Only in those abnormal cases where a race of one type is subject to a race of much-superior type, is this qualification pertinent. In our own case, as in the cases of all societies having populations approximately homogeneous in character, and having institutions evolved by that character, there may rightly be aimed at the greatest rigor possible. The merciful policy, no less than the just policy, is that of insisting that these all-essential requirements of self-support and non-aggression shall be conformed to—the just policy, because failing to protect the better or more-adapted natures against the worse or less-adapted; the merciful policy, because the pains accompanying the process of adaptation to the social state *must* be gone through, and it is better that they should be gone through once than gone through twice, as they have to be when any relaxation of these conditions permits retrogression.

Thus, that which sundry precepts of the current religion embody—that which ethical systems, intuitive or utilitarian, equally urge, is also that which Biology, generalizing the laws of life at large, dictates. All further requirements are unimportant compared with this primary requirement, that each shall so live as neither to burden others nor to injure others. And all further appliances for influencing the actions and natures of men are unimportant compared with those serving to maintain and increase the conformity to this primary requirement. But, unhappily, legislators and philanthropists, busy with schemes which, instead of aiding adaptation, indirectly hinder it, give little attention to the enforcing and improving of those arrangements by which adaptation is effected.

And here, on behalf of the few who uphold this policy of natural discipline, let me emphatically repudiate the name of *laissez-faire* as applied to it, and emphatically condemn the counter-policy as involving a *laissez-faire* of the most vicious kind. While holding that, when the State leaves each citizen to get what good for himself he can, and to suffer what evil he brings on himself, such a let-alone policy is eventually beneficial, I contend that, when the State leaves him to bear the evils inflicted by other citizens, and can be induced to defend him only at a ruinous cost, such a let-alone policy is both immediately and remotely injurious. When a Legislature takes from the worthy the things they have labored for, that it may give to the unworthy the things they have not earned—when cause and consequence, joined in the order of Nature, are thus divorced by statesmen—then may properly come the suggestion, "Cease your interference." But when, in any way, direct or indirect, the unworthy deprive the worthy of their dues, or impede them in the quiet pursuit of their ends, then may properly come the demand, "Interfere promptly and effectually, and be in fact the protectors which you are in name." Our politicians and philanthropists, impatient with a salutary *laissez-faire*, tolerate and even defend a *laissez-faire* that is in the highest degree mischievous. Without hesitation, this regulative agency we call the Government takes from us some £100,000 a year to pay for art-teaching and to establish art-museums; while, in guarding us against robbers and murderers, it makes convictions difficult by demurring to the cost of necessary evidence: even the outlay for a plan, admitted by the tax-master, being refused by the Treasury! Is not this a disastrous *laissez-faire?* While millions are voted without a murmur for an expedition to rescue a meddling consul from a half-savage king, our Executive resists the spending of a few extra thousands to pay more judges: the result being not simply vast arrears and long delays, but immense injustices of other kinds—costs being run up in cases which lawyers know will never be heard, and which, when brought into court, the over-burdened judges get rid of by appointing junior counsel as referees: an arrangement under which the suitors have not simply to pay over again all their agents, at extra rates, but have also to pay their judges.[1] Is not that, too, a flagitious *laissez-faire?* Though, in our solicitude for Negroes, we have been spending £50,000 a year to stop the East-African slave-trade, and failing to do it, yet only now are we providing protection for our own sailors against unscrupulous ship-owners—only now have sailors, betrayed into bad ships, got something more than the option of risking death by drowning or going to prison for breach of contract! Shall we not call that, also, a *laissez-faire* that is almost wicked in its indifference? At the same time that the imperativeness of teaching all children to write, and to spell, and to parse, and to know where Timbuctoo lies, is being agreed to with acclamation, and vast sums raised that these urgent needs may be met, it is not thought needful that citizens should be enabled to learn the laws they have to obey; and though these laws are so many commands which, on any rational theory, the Government issuing them ought to enforce, yet in a great mass of cases it does nothing when told that they have been broken, but leaves the injured to try and enforce them at their own risk, if they please. Is not that, again, a demoralizing *laissez-faire*—an encouragement to wrong-doing by a half-promise of impunity? Once more, what shall we say of the *laissez-faire* which cries out because the civil administration of justice costs us £800,000 a year—because to protect men's rights we annually spend half as much again as would build an iron-clad!—because to prevent fraud and enforce contracts we lay out each year two-thirds of the sum our largest distiller pays in spirit-duty!—what, I ask, shall we say of the *laissez-faire* which thus thinks it an extravagance that one-hundredth part of our national revenue should go in maintaining the vital condition to national well-being? Is not that a *laissez-faire* which we might be tempted to call insane, did not most sane people agree in it? And thus it is throughout. The policy of quiescence is adopted where active interference is all-essential; while time, and energy, and money, are absorbed in interfering with things that should be left to themselves. Those who condemn the let-alone policy in respect to matters which, to say the least, are not of vital importance, advocate or tolerate the let-alone policy in respect to vitally-important matters. Contemplated from the biological point of view, their course is doubly mischievous. They impede adaptation of human nature to the social state, both by what they do and by what they leave undone.

Neither the limits of this chapter, nor its purpose, permit exposition of the various other truths which Biology yields as data for

[1] And even then there are often ruinous delays. A barrister tells me that in a case in which he was himself the referee they had but six meetings in two years.

Sociology. Enough has been said in proof of that which was to be shown—the need for biological study as a preparation for grasping sociological truths.

The effect to be looked for from it is, that of giving strength and clearness to convictions otherwise feeble and vague. Sundry of the doctrines I have presented under their biological aspects are doctrines admitted in considerable degrees. Such acquaintance with the laws of life as they have gathered incidentally, lead many to suspect that appliances for preserving the physically-feeble bring results that are not wholly good. Others there are who occasionally get glimpses of evils caused by fostering the reckless and the stupid. But their suspicions and qualms fail to determine their conduct, because the *inevitableness* of the bad consequences has not been made adequately clear by the study of Biology at large. When countless illustrations have shown them that all strength, all faculty, all fitness, presented by every living thing, has arisen partly by a growth of each power consequent on exercise of it, and partly by the more frequent survival and greater multiplication of the better-endowed individuals, entailing gradual disappearance of the worse-endowed — when it is seen that all perfection, bodily and mental, has been achieved through this process, and that suspension of it must cause cessation of progress, while reversal of it would bring universal decay—when it is seen that the mischiefs entailed by disregard of these truths, though they may be slow, are certain—there comes a conviction that social policy must be conformed to them, and that to ignore them is madness.

Did not experience prepare one to find everywhere a degree of irrationality remarkable in beings who distinguish themselves as rational, one might have assumed that, before devising modes of dealing with citizens in their corporate relations, special attention would be given to the natures of these citizens individually considered, and by implication to the natures of living things at large. Put a carpenter into a blacksmith's shop, and set him to forge, to weld, to harden, to anneal, etc., and he will not need the blacksmith's jeers, to show him how foolish is the attempt to make and mend tools before he has learned the properties of iron. Let the carpenter challenge the blacksmith, who knows little about wood in general and nothing about particular kinds of wood, to do his work, and, unless the blacksmith declines to make himself a laughing-stock, he is pretty certain to saw askew, to choke up his plane, and presently to break his tools or cut his fingers. But, while every one sees the folly of supposing that wood or iron can be shaped and fitted, without an apprenticeship during which their ways of behaving are made familiar, no one sees any folly in undertaking to devise institutions, and to shape human nature in this way or that way, without a preliminary study of Man, and of Life in general as explaining Man's life. For simple functions we insist on elaborate special preparations extending through years; while for the most complex function, to be adequately discharged not even by the wisest, we require no preparation!

How absurd are the prevailing conceptions about these matters, we shall see still more clearly on turning to consider that more special discipline which should precede the study of Sociology; namely, the study of Mental Science.

THE INTELLECTUAL POWERS OF BIRDS.

THE *Popular Science Review* for July contains some interesting but too brief remarks by Mr. Leith Adams on the "Mental Powers of Birds," which it is interesting to define specifically as distinguished from the mental powers of other animals of the higher order of sagacity. This we will briefly do. First, it would appear from Mr. Darwin's discussions—though Mr. Leith Adams hardly refers to them—that none of the lower orders of creatures have so keen an appreciation of beauty as many kinds of birds, and certainly that none turn this taste for beauty so deliberately to the purpose of social amusement. That great naturalist has described how some kinds of birds really celebrate festivities very closely approaching to our wedding *fêtes*, balls, and garden parties, in places carefully decorated and arranged by the birds for the purpose of social gatherings, and which are not used for their actual dwelling-places. The best evidence, says Mr. Darwin, of a taste for the beautiful "is afforded by the three genera of Australian bower-birds. . . . Their bowers where the sexes congregate and play strange antics" (at all stranger than our waltzes and quadrilles?) "are differently constructed; but, what most concerns us is, that they are decorated in a different manner by the different species. The satin bower-bird collects gayly-colored articles, such as the blue tail-feathers of paroquets, bleached bones and shells, which it sticks between the twigs, or arranges at the entrance. Mr. Gould found in one bower a neatly-worked stone tomahawk and a slip of blue cotton, evidently procured from a native encampment. These objects are continually rearranged and carried about by the birds while at play. The bower of the spotted bower-bird is beautifully lined with tall grasses, so disposed that the heads nearly meet, and the decorations are very profuse. Round stones are used to keep the grass-stems in their proper places, and to make divergent paths leading to the bower. The stones and shells are often brought from a great distance. The regent-bird, as described by Mr. Ramsay, ornaments its short bower with bleached land-shells belonging to five or six species, and 'with berries of various colors, blue, red, and black, which give it, when fresh, a very pretty appearance. Besides these, there were several newly-picked leaves and young shoots of a pinkish color, the whole showing a decided taste for the beautiful.' Well may Mr. Gould say, 'These highly-decorated halls of assembly must be regarded as the most wonderful instances of bird-architecture yet discovered;' and the taste, we see, of the several species certainly differs." You could not have distincter evidence in a lady's *salon* carefully decorated with flowers, either of her taste for the beautiful, or of the deliberate subordination of that taste to social purposes, than we have here of the same qualities in birds. Mr. Leith Adams in his paper hardly refers, as we have already observed, to this remarkable class of facts at all, only pointing out that the obvious preference for gayly-colored plumage on the part of the females clearly implies a genuine taste for the beautiful in birds, which is, of course, true, but is not nearly as good evidence of a distinct intellectual development on this point as the elaborate decoration of their bowers by birds for festive purposes. The mere preference of gay colors may be unconscious and purely instinctive, but when a bird looks out for bleached land-shells and tall grasses to ornament its reception-room, and fetches round stones to "fix" the grasses in their proper place, and then uses the hall thus provided only for festive social purposes, you can hardly deny such birds either the powers or the tastes of landscape-gardeners and ball-givers. And we fancy this kind of deliberate taste for the beautiful, and the beautiful in subordination to social purposes, is confined among the lower animals to birds; and, as regards the social purposes, to a very few orders of birds. A great many birds seem to have more appreciation of beauty of color than almost any other class of animals, but only in a few species has it risen to the point of a really decorative social art. We may gather from this that in the bird the perception of harmony is of a very high kind, and this evidently applies to sound as well as color. No creatures utter sounds so full of beauty, or display such wonderful qualifications for imitating the beautiful sounds they hear. Must we not say, then, that the bird has, in more force than any other species of the lower animals, the perception of harmony in forms, colors, and sounds, and the further consciousness of the fascination such harmony has for its own species, and the enhancement it lends to social enjoyments?

Another great mental quality which birds seem to have in excess of other animals is a very fine calculation of distance, and this, too, in direct subordination to their own well-being. It has been shown again and again—and Mr. Leith Adams refers to some facts in support of it in this essay—that, as new weapons of offence are invented, many species of birds narrowly observe the range of the new bows or guns, and keep out of range, not even troubling themselves to go at all farther than is necessary to be out of range. Quite recently we have read, though we cannot verify the reference at present, of some birds which adapted themselves within a few days to the increased range of the rifle, directly after they had learned its range for the first time, having been previously accustomed only to the fowling-piece, and kept just outside the two thousand yards' range, or whatever range it was, retaining their composure perfectly at that distance. We suppose the wonderful accuracy of the travelling birds in striking the exact point for which they are bound, of which Mr. Leith Adams gives us wonderful illustrations, is a still greater proof of the same power. Mr. Adams tells us of swifts which, after eight months' absence in the South—at a distance of some 1,800 or 1,900 miles—return not merely to the same region, but to the same nests which they had deserted, and that, too, year after year—the individuals having been marked so that there could be no mistake as to their identity, unless indeed there be such creatures as claimants to abandoned nests even in the ornithological world. Again, the delicate adaptation of the power of geometrical measurement to the welfare of its species seems to be shown by the weaver-bird of India, which hangs its "elaborately-constructed, purse-shaped nest" "from the tops of branches overhanging deep wells," in order to render it particularly difficult for enemies to get at the nest without running a great risk of falling into the well.

Again, none of the lower animals, except the monkey, seem to have so much imitative power, particularly in relation to sounds—the imitative power of monkeys has more of capacity in it for imitating gestures—as parrots, mocking-birds, ravens, and other tribes of birds. Curiously enough, this seems to be more or less a quality of tame, as distinguished from wild birds. At least, Mr. Leith Adams says that parrots, the cleverest of all these imitators when in captivity, "are not by any means given to copy the call-notes of other birds in their native woods," so that imitation would seem to be the channel into which their intellectual energy is apt to be directed, when they are robbed of their natural occupations. That is, we suppose, their perceptions being very acute, and their voice well developed, directly they are cut off from their usual occupations, they begin to imitate all they hear by way of exercising their latent faculties. That birds can go beyond mere imitation, and are to some extent accomplished actors, the evidence as to all those birds which, by false pretences of agitation, lure the trapper away from the vicinity of their nest, completely shows. Mr. Leith Adams bears witness to this, and tells besides the story of the trick played by the ruby-throated humming-bird of Canada, which, if captured, "feigns death by shutting its eyes and remaining quite motionless," and then suddenly makes a vigorous effort to escape. This shows not merely a dramatic gift, but a distinct purpose in the use of it. *Ruses* of a similar kind are, however, not unexampled in other animals and birds. Cats, for instance, constantly feign sleep, for the purpose of catching birds or mice more effectually.

On the whole, however, it may be safely said that birds seem to have much more capacity for perceiving beauty, much more gift for social enjoyment, a finer knowledge of distance and direction, and more power of vocal imitation, than any other order of animals of which we know any thing. On the other hand, they have less sense of power and sympathy than the dog, and therefore much less sense of responsibility to their superiors, whom they often love, but seldom serve. Perhaps we might generalize these mental qualifications by saying that birds are chiefly educated by perceptions, wonderfully accurate indeed, but still of things at a distance, of things at an almost telescopic range; that their rapidity of flight makes them creatures of *wide* experience, but not of *full* experience of any species but their own; and that, as a result, they cannot know men well enough to learn as much from men, as dogs, and cats, and elephants, and even other orders of creatures learn. Birds, in short, get bird's-eye views of the earth, and bird's-eye views, however instructive to those who have previously mastered the details carefully, do not exactly furnish a good basis for progressive knowledge. They obviously get a knowledge of geography, and, in some sense, of the air and its currents, such as no other creatures can have. They have an ear for music, and an eye for harmony of form and color, and probably of movement—for there are bird-dances which Taglioni would have despaired of imitating—such as no other member of the animal world possesses; and the perception of beauty, we know, depends on nothing so much as the *coup d'œil*, and this birds can always command. But they lose, by their great privilege of wings, that slow and sure experience of the ways of man which some less-gifted animals acquire. A swift which flies at the rate of 270 miles an hour, according to Mr. Leith Adams, clearly cannot have a brain to utilize an experience acquired at that rate in any but a very perfunctory way. Therefore, though birds have so strange a perception of beauty, which hardly needs close analysis, they are too fast, too migratory in their habits, to learn any thing which needs perfect fidelity and vigilance confined to a very narrow circle of facts. They are the musicians, and we might almost say the sensuous poets of the animal world; but musicians and sensuous poets do not conduce to progressive knowledge and ethical culture. Birds range too high and fly too fast for sympathy with man, and so it happens that their intellectual powers, remarkable and unique as they are in the animal world, never become so human and so almost spiritual as those of creatures which can only boast of very inferior powers.—*Spectator.*

HYPNOTISM IN ANIMALS.

By Prof. JOSEPH CZERMAK.[1]

TRANSLATED FROM THE GERMAN, BY CLARA HAMMOND.

GENTLEMEN: I propose in two lectures to bring to your notice a subject which, in very many respects, is one of great and increasing interest.

The physiological facts which I shall demonstrate and discuss, as they occur in various animals, are remarkably surprising. They will afford us opportunities for making deductions which are interesting in their historical relations, and they will also serve to demonstrate to us how man, uneducated in natural science, is deficient in judgment when he comes to view unfamiliar incidents of Nature. They will show us that such a man examines natural phenomena in a way which is certain to deceive him, by convincing him that he has observed events which in reality never occurred.

The obstinacy and lack of discernment which he thus brings to bear on his investigations are truly astonishing; and it is not surprising, therefore, that the intelligent inquirer into the operations of Nature should place little reliance on the testimony of highly-honorable persons whose minds are untrained to the work they have undertaken. Even when such persons are possessed of great culture—even perhaps in natural science—but are not infused with that spirit of exact investigation so necessary to the discovery of truth in Nature, we are justified in regarding their statements with hesitation and suspicion. Often, very often, we are obliged to listen to relations of unusual or dubious natural events, and cannot avoid feeling irritated at the assertions—which the speaker regards as putting an end to all argument—"I was there. I saw it all with my own eyes, and heard it with my own ears. What I report is actually true!"

The relator has really been present; he has seen and heard every thing of which he speaks; he is in real earnest, and he tells the truth; and yet what he reports has never taken place, and the real investigator of Nature is perfectly right in disregarding his testimony, while, at the same time, his truthfulness is not questioned.

This may strike you as paradoxical. It is so, however, only in appearance, for the discrepancy disappears when we come to make the discovery that it is the perception of the observer which is at fault, and that the eyes and ears have been correct, so far as their functions were concerned. The circumstance is what I call *an event viewed unequally*.

[1] These lectures were delivered by Professor Czermak (pronounced Tshermak) in the private physiological laboratory of the University of Leipsic, on the 24th and 25th of January, 1873.

In the want of discernment in which such an observer is placed, when investigating Nature, he regards the temporary coincidences and consequences of certain real events as in themselves real. He accepts these circumstances at once, and without thorough investigation, as having an intimate and direct relation with real events. He, therefore, forms a conception of something which is not real, and he reports as an actual occurrence that which, in the way he means, never in fact took place. Such a circumstance constitutes an event not thoroughly tested, or an incident unequally investigated, and, I believe, we are not merely logically justified, but morally forced, to distinguish, among events in the perception of Nature, a new and especial category, that of *events viewed unequally*. In this category are embraced circumstances which play a most extensive *rôle* in the history of the development of the human mind. Without the conception of this class of supposed incidents, we would never be capable of understanding and explaining certain obscure appearances and tendencies of the human mind, and the persistency with which they rise and maintain themselves as often as they are overthrown, and when they have scarcely even had time to disappear.

Nothing strengthens the mind like a habit of investigating natural events with thoroughness and strictness. Without this habit, credulity and superstition can neither be broken nor restrained.

We children of the nineteenth century are not a little proud of our civilization, culture, and enlightenment. And yet, if a comparison were made between the ruling mind of the middle ages and that which now reigns, no great progress would be perceived. In fact, we have no right to plume ourselves on the material development of our era, so long as certain tendencies of the mind remain as they were ages ago, and while we are no more capable, than we were then, of investigating natural events, so as to deduce the truth from them.

It would carry me too far from my subject if I were to give even a hasty glance at all those tendencies and false appearances which, so to say, calumniate our enlightened and cultivated life. It will suffice merely to mention the manias of table-turning, spirit-rapping, spiritual apparitions, animal magnetism, and clairvoyance. To-morrow, at the conclusion of the second lecture, I will give a more detailed account of these subjects, as they appear in the light of facts. In what I have said this morning, I wished principally to prepare your minds for the facts I am about to state, and for the proper consideration of certain apparently wonderful physical phenomena which, though partially known for some time, have received no scientific investigation, and which, therefore, have not been awarded their proper place in the domain of nervous physiology.

During the autumn of the past year, while sojourning in Bohemia, I made the acquaintance of a gentleman who, in the course of one of our scientific discussions, communicated to me the striking information that he had not only seen others magnetize crawfish, but had himself succeeded in the attempt. On being asked for fuller particulars as to what he meant, the gentleman told me that the whole thing was uncommonly simple.

You hold the crawfish firmly in one hand, and with the other make magnetic strokes from the end of the animal toward the head. If, in the mean while, when making these passes in the given direction, and carefully avoiding any other movement, the tips of the fingers are placed at the animal's back, it forms an arch as the hand is withdrawn. Under this manipulation the crawfish, in a short time, becomes quiet, places itself on its head in a vertical position, using its feelers and the two claws, which are pushed inward, as a support. In this peculiar and unnatural position the animal remains motionless, until passes are again made in the opposite direction, beginning at the head, at which it begins to move once more, tries to lose its equilibrium, at last falls, and crawls away.

As my informant was known to be an intelligent man, and of a most credible, honorable character, of course I could entertain no doubt respecting the veracity of this simple, clear, though remarkable statement, and least of all could I have expressed such a doubt to him; but my knowledge of Nature led me to say to him that, although I placed the utmost belief in his communication, I was of the opinion that he had related to me an "event viewed unequally."

Indeed, that the crawfish placed itself on its head, and remained motionless in this position after having the passes made over it, was certainly an actual circumstance, inasmuch as he testified to it; but that the so-called "magnetic" strokes with the finger-tips, and the action of magnetizing, were the actual cause of the crawfish's condition, was, for me, in spite of his testimony, and without wishing to presume upon him, no real incident, that I could accept on faith and belief, or, above all, consider worthy of an earnest inspection; because this was in no way the object of his perception and examination.

I desired him to show me the experiment—not that I expected a demonstration, nor that I doubted his facts—but mainly because I had nothing better to do, and I thought I would be able to promise him on this occasion a clearer idea of moderate perceptions in Nature, as a slight service on my part, and show him, with an example, what an "event viewed unequally" was. No sooner said than done. The order was given to procure crawfish from a neighboring brook, and we soon had a basketful before us.

What then happened I will illustrate to you in the same way that we performed the experiment then, for I have here in this vessel a number of crawfish all ready. My friendly companion, sure of the result of his experiment, seized one of the animals and began his "magnetic" strokes, from the end toward the head, exactly as I am doing now. The crawfish, which at first resisted, gradually became calm;

and now, indeed, his crooked tail high in the air, he places himself on his head, and remains motionless, as if asleep, in this forced and unnatural position; while he finds his support in his feelers and two under claws.

It is really a surprising sight! While we then, as now, saw the conclusion of the experiment with satisfaction and interest, I, on my part, had seized an animal with the intention of endeavoring to place it on its head, without the magnetic strokes, and thereby to remove the reasonable thought of a secret "magnetic" influence contained in the strokes.

And see!—my crawfish, after in vain struggling in my firm grasp, actually stood just as motionless on its head as the one which my compainion had magnetized, and as this one here which I have placed before you on its head, without all that deceptive magnetism. And how was it with the opposite strokes, beginning from the head? My friend worked zealously with these strokes upon his crawfish, while I represented the opposite experiment. It lasted some time, until the crawfish began to move, and at last fell over and crawled away.

You see that my strokes here with this crawfish have so far no result, and I fear you will lose all patience. Indeed, let us confidently interrupt this opposite manipulation, and let us rather place the rest of the crawfish, without magnetism, on their heads, in order to confirm this striking circumstance again. The longer we wait before resuming the magnetic strokes from the head, the more sure we are at last to reap the benefit. It is the same with this as with the solemn request of a Catholic parish in Austria to their priest, which was, to send rain from heaven upon their parched fields, to which, however, the enlightened "Joseph," in order to postpone it a little, said: "Yes, willingly, children!—but not just yet, the barometer has been much too high for some time past!" Let us then follow the good advice of the wise pastor; you will see yourselves, if you wait, that gradually all the crawfish, standing motionless on their heads, move again of their own accord, without any mysterious manipulation! In regard to the influence of the other motion, it is nothing at all. We are able to act upon the altered nervous system of the crawfish by mechanical means, through the influence of a stream of air, through a sudden coolness or warmth, or through the natural disturbance previous to the awakening; that is, the restoration of the normal functional capacities.

You also see, gentlemen, our experiment then and now has terminated exactly as I predicted, and I hope that you will now be convinced, as my companion was, that the so-called "magnetizing" of the crawfish is an actual event; but, as I say, one "viewed unequally," and, *therefore, not one!* At the same time, the idea will become clear and distinct to you, which I have associated with the description of "events viewed unequally," and the reason that I have chosen this particular description, to demonstrate something which is not an event at all, will be apparent to you.

The only actual fact in the "magnetism" of the crawfish is the motionless state which follows the strokes in the air. While one considers this actual succession, without any examination, to be a mysterious connection of the "magnetic" influence, so one thinks this non-existing connection to be a real event, and decidedly true. Therefore, I call such events which never took place, none the less circumstances, but, in order to distinguish them from actual ones, I designate them as "viewed unequally." I do this in order to indicate the characteristic circumstance that, in the foundation, something of actuality exists, and thus gives them an appearance of reality. This immediately strikes the person whose judgment is not altogether exact, and can only be removed by a close examination and inspection. This last, however, is not the case with every one, and thus the great powers of reason and prudence which execute these events explain themselves, and also explain the immense *rôle* which they play in the history of human error.

In the so-called magnetizing of the crawfish, the only actual incident is the one already mentioned. This is simple enough, as the crawfish possesses the remarkable quality of being able to lose the normal excitation and power of acting belonging to its nervous system, and is also capable of supporting itself, when it is placed gently in some particular position, in spite of its former resistance. As to the magnetic strokes, they have certainly no significance.

That, however, the actual change of posture in the crawfish does not depend upon a mysterious magnetic fluid, which proceeds from the fingers and hands of the experimenter, is proved by the attempt in which the crawfish is not touched and held by the hand in any way. In this experiment the crawfish is held by a string, and that striking condition of immobility, which lasts some time and then disappears, is just as apparent in it as in the others.

I will place a loose string around the tail of this crawfish, without moving the animal, draw the ends lightly together, and hang the crawfish by means of it on this frame. You see how the animal, with its head downward, in vain strives to free itself from its unnatural position. This, however, does not last long. It becomes quiet, and finally hangs completely motionless, as though it had been held firmly in my hand. This continues until it sooner or later begins again to move of its own accord.

With a glass tube I will roll this second crawfish on its back; it endeavors to regain its proper position; but, in consequence of being prevented with the glass tube, it does not succeed. The animal's resistance is fruitless; the tube holds it firmly, and see! it now remains quiet on its back, and will sooner or later move again of its own accord.

Now, as in the former experiment, we can no longer speak of a magnetic influence, proceeding from the experimenter, but, nevertheless, in both cases, the crawfish remained motionless after its first resistance was made unsuccessful, by means of the tube and pure mechanical force. But crawfish, which crawl briskly in their course backward, often remain for some time motionless, a result which is caused by no visible circumstance. We thus learn that normal, unmolested crawfish can become motionless, just as well as the ones we experiment with, only the mysterious character of these experiments does not lose all its interest, for we see that the immobility which we occasion by our preparation cannot be prevented, while the crawfish which is not subjected to our manipulations becomes motionless through no demonstrable or extraordinary circumstance. Again, we see that the experimental crawfish become immobile, and remain so, notwithstanding that, in consequence of the unnatural positions in which they are placed, they are exposed to a powerful inducement to move, and cannot be quite determined as to the normal condition and degree of excitability of their nervous systems. The unmolested crawfish, however, experiences no such emotion.

Of the latter, which fall into a motionless state and remain so, two kinds may be seen. Either the crawfish is in a normal and wakeful condition, and does not move because it has no motive for doing so, and consequently does not wish to move, or else it cannot move because it is exhausted, or finds itself in a state of lethargy and sleep. In regard to our experimental animals there is no doubt, as already stated, that they are placed in positions in which they would move if they could, that is, if they were in a condition capable of working their nervous system.

And thus you see how, through a minute and scientific inspection, we have arrived at the fact that, instead of finding the actual circumstance by magnetizing the crawfish, the animals in winter and autumn, when their instinct is duller than at other seasons, possess the remarkable quality of losing the normal excitability of their nervous systems, even in the most forced positions; also that they are again able to maintain their equilibrium in spite of resistance made at first, after they have been held firmly a certain time.

I remember once seeing a like effect in hens which had been experimented upon in the same way. I had already known of this fact, but had never possessed the opportunity or occasion to give it a strict investigation. I therefore concluded to experiment upon the poultry-yard of my hospitable country-friend with whom I was then staying. Many of you, no doubt, have been told, or else know from your own experience, that wild, frightened hens which one has had great difficulty in catching and holding, are liable to become completely motionless as if enchanted by some magical spell, after being held with gentle force upon the floor or table where a chalk-line has been drawn the length of the beak or diagonally from each eye. Now, although this sounds very incredible, it is an actual fact and I will endeavor to demonstrate it to you. Yet, I am obliged to say expressly beforehand that I cannot promise you this experiment will succeed, in consequence of this large assembly, the light, and the room, which, in spite of the quiet and attention, is not wholly free from noise. I have never performed this experiment under such circumstances, and therefore cannot say whether any disturbing influence would affect my hen.

I must call to your remembrance, for my own safety as a careful and circumspect experimenter, that we are making a new experiment, or, in fact, an old one under somewhat altered circumstances. Therefore we must be fully prepared to make a new discovery, which will probably undeceive us in no agreeable manner, if it robs us of the pleasure of confirming, now and here, the wonderful accounts relative to the condition in which a timid hen can be placed after such apparently insipid and senseless preparations.

(The lecturer caused one of his assistants to bring him a hen and hold it fast upon the table. This was done after much resistance and many cries from the frightened bird; then with his left hand he held the head and neck of the hen upon the table, and with his right hand drew a chalk-line, beginning from the end of the beak, on the flat surface, which was of a dark color. Left entirely free, the hen, though breathing heavily, remained entirely quiet upon the table; then, without moving, it allowed itself to be placed on its back, and remained in this unnatural position until the close of the lecture. It only awoke when the audience began to leave.)

When I performed this experiment for the first time and with the same result as you now see, I was for the moment dumb with astonishment, for the hen not only remained motionless in its unnatural and forced position, but did not make the slightest attempt to fly away or to move in any manner whatever when I endeavored to startle it. It was clear the hen had lost the entire normal functional capacities of its nervous system under the apparently indifferent and useless arrangement of the experiment, and had been placed in this remarkable condition as though by magic. This state is characterized by a greater or a less suspension of its intelligence or will.

But *nil admirari* is the first maxim of the moderate investigator of nature. We must now ascertain the actual connection of these phenomena, so as not to stand still at an "event viewed unequally," like old Athanasius Kircher, the celebrated *savant* and Jesuit from Fulda, who affirmed this mysterious result in one of his works which appeared in Rome about 1646, "*Ars magna lucis et umbræ*," as a positive corroboration of the immense imagination of hens. Kircher performed the experiment (which he called "*experimentum mirabile de imaginatione gallinæ*," and illustrated excellently with a fine woodcut) in the following way:

He first tied the hen's feet together with a narrow ribbon and laid the animal on the ground, where after many cries and violent struggling it became quiet, "as if," he says, "despairing of escape through the fruitlessness of its motions, it gave itself up to the will of its conqueror." Then Kircher drew a chalk-line in a diagonal direction from one eye to the other, loosened the ribbon, and the hen, although left perfectly free, remained immovable, even when he attempted to rouse it.

Therefore Kircher affirms that the hen thinks the chalk-line a string by which it is bound as at its feet, notwithstanding that the ribbon has been loosened. This he attributes to the force of the animal's imagination.

In this way Kircher reports something which never took place, although his confirmation partakes of reality. He also places his assertions in that fatal category of "events viewed unequally," which plays such an important *rôle* in the history of human error.

As soon as I had recovered from my extreme astonishment at the magical effect which I perceived at the first experiment I made, I immediately rubbed out the chalk-line. My astonishment, mingled with satisfaction, returned for a moment, as I saw the hen remain motionless although the chalk had entirely disappeared. The chalk-line appeared just as unnecessary as at the first and following experiments. Certainly this might have resulted from an after-effect of the line. In order to inspect this more clearly, I performed my experiment so that I held the hen firmly for some time, and stretched out the head and neck as if I were going to draw the chalk-line, but in reality did not do it. And lo! the hen remained just as immovable as if the line had really been there!

It is therefore an actual fact that the chalk-line and ribbon are entirely unnecessary. What Kircher affirms relating to the imagination of the hens in regarding the chalk-line as a band which holds them, is only an "event viewed unequally," consequently no event at all. Observe that the only actual fact in Kircher's report is the motionless condition of the hen after the line has been drawn. While he takes this temporal coincidence without further investigation for an actual event caused by the hen's power of imagination, he reports a circumstance which really never happened, at least not in the way he thinks.

Through my simplified arrangement, without either chalk or string I have not only placed hens in this stupefied condition, but also geese, ducks, turkeys, and even a timid, unruly swan. This state makes the animals incapable of escaping, or even of changing their forced positions. This strange condition lasts often for a minute, indeed, frequently a quarter of an hour and longer, and is so intense that the animals can only be roused after repeated blows. Yes, the animals —as you have seen yourselves—can be turned over on their backs without awaking or showing the least resistance. When they are thus moved one can frequently perceive that the head of the hen, as though held by an invisible hand, keeps its proper position, while the neck is twisted. At the same time, the foot on the side which did not come in contact with the floor when the animal was moved, is drawn up with the claws cramped, while the foot on the other side is stretched downward. So the hens remain, just as ours is here on the table, for a long time, breathing heavily, but otherwise completely motionless on their backs, until at last either by themselves or by some other means they are aroused and fly away.

My experience with simply holding down the necks and heads of the hens on the ground did not prove efficacious with all hens, and was more or less so with the same ones at different times and under different circumstances. Wild hens seem better for this experiment than those which have already been used and which are accustomed to be near people. Under all circumstances the success of my simplified experiment proves that the tying of the hen's feet, and the drawing of the chalk-line, as Kircher did, are entirely unnecessary. The moment when the remarkable change takes place concerning the capabilities of the hen's nervous system, appears to be at the stretching out of the head and neck, where possibly a slight mechanical extension of certain parts of the brain may take place, apart from the fear which the animal experiences at being held forcibly.

The chalk-line and the oppression of the tight band which are actually quite dispensable, appear, on the other hand, open to pure deception. I myself was deceived at first. We must only be careful not to stand still at "an event viewed unequally," as the unlearned do. For the complete dispensableness of the string and chalk-line does not prove its absolute indifference and ineffectiveness; and, on the other hand, the gentle, mechanical extension of the brain and spinal marrow, in consequence of the equalization of the curvature which takes place in the vertebral column at the forcible stretching out of the head and neck, is a very plausible thought, though not exactly a thoroughly well-founded one. There is nothing else to be done. We must patiently and circumspectly continue our investigation and experiment, in order to find the actual connection of the phenomena.

You see that firm, strict, natural investigation is no child's play. It demands simple and proportionate incidents, an insight, a circumspection and criticism, which the people who proclaim and testify to the reality of moving tables, flying guitars, self-playing pianos, rappings, etc., as spiritual manifestations, do not possess. Yes, if it were so easy and simple to discover new features of Nature, or only to find out natural scientific incidents, certainly every one could be an "investigator."

I might have occasion here to express the just indignation which the unscientific and frivolous man infuses into the mind of an investigator of Nature. But our limited time to-day has passed so quickly that I will close with this remark: Above all, it is not my intention to express different frames of mind and subjective feelings, but—the next time — to complete the investigation of Kircher's "*experimentum mirabile*." I do this, finally, in order to be able to follow it with a general experimental investigation of spiritualism and spiritual manifestations, which all those who are capable of an unprejudiced deliberation may find clear and comprehensible. Till to-morrow, then.

TONGUELESS SPEECH.

By W. J. YOUMANS, M. D.

MANY animals possess the attribute of voice, but man is the only one among them all capable of modulating voice into speech. This he does by changing the shape of the cavities of the throat, mouth, and nose, by the actions of the muscles which move the walls of those parts, and by the movements of the tongue. The latter organ is commonly credited with the most important share of the work; a distinction to which, as we shall soon see, it is far from being entitled.

The sounds of the vowels, in ordinary speech, are produced by a continuous expiration, the mouth being kept open, and the form of its aperture changing with the utterance of each. Certain consonants may also be pronounced, without interrupting the current of expired air, by alterations in the shape of the throat and mouth: *h*, for example, is the result of a little extra expiratory force; *s*, *z*, *sh*, and *j* in some cases, *th*, *l*, *r*, *f*, and *v*, may likewise all be produced by continuous currents of air forced through the mouth, the shape of the cavity of which is peculiarly modified by the tongue and lips. All the other consonantal sounds of the English language involve the blocking of the air-current in its passage through the mouth. In the case of *m* and *n*, it is prevented from issuing through the lips, and is forced through the nose; while the remaining consonants, termed explosives, such as *b* and *p*, are produced by shutting the passage in both mouth and nose, and forcing the vocal current through the obstacle furnished by the mouth, changes in the form of which give to each consonant its peculiarity.

This, in brief, is the explanation given by Huxley, of the formation of articulate sounds; and it will be seen that, while the tongue is intimately concerned in modifying the shape of the oral cavity, only a few of the sounds, such as those of *d*, *t*, *s*, *sh*, *l*, and *r*, and sometimes *g*, require its presence, and most of these even may be approximately sounded without it. In his "Elementary Lessons in Physiology," Prof. Huxley relates the case of a man, examined by him, whose tongue had been removed as completely as a skilful surgeon could perform the operation, two inches and a half of the member having thus been lost. The stump could be seen occupying a position as far back as the anterior pillars of the fauces, forward of which point, when the mouth was open, it could not be advanced. Yet this person could talk with little apparent difficulty, giving most of the sounds with ease: *s* and *sh*, *l*, and *r*, and final *g*'s, were more or less imperfect, but *d* and *t* were the only ones completely beyond his power. Well-authenticated cases of a similar character have, from time to time, been recorded; a few of the more remarkable of which are given in the following pages.

Cutting out the tongue was a form of punishment frequently inflicted in ancient times. In A. D. 484, sixty Christian confessors of Tipasa, a maritime colony on the north coast of Africa, had their tongues cut out by order of Hunneric, the Vandal conqueror; but, in a short time, some of them at least were able to speak with such distinctness that they went about preaching again. Pope Leo III. is said to have suffered a similar mutilation in 799, and afterward regained his speech. In the sixteenth century, a band of French Protestants were condemned to have their tongues cut out before they were led to the stake. One of them, immediately after the execution of the sentence, repeated three times, "Le nom de Dieu soit béni!" (God's name be blessed). In another case, the martyrs spoke so distinctly after losing the tongue, that the executioner was accused of having failed to carry out the sentence.

The ability to speak, after being thus deprived of the tongue, was long accounted miraculous, and regarded as a signal mark of divine favor. Even as late as the present generation this view of the matter has been maintained, in spite of the fact that the accumulated experience of surgeons has demonstrated it to be an entirely natural result, with nothing miraculous about it.

Sir John Malcolm, writing from Persia in 1828, describes the case of a chief named Zâl Khan, who, coming into disfavor with the reigning monarch, was condemned to have his eyes put out. Failing in his appeal for a recall of this cruel sentence, Zâl Kahn "loaded the tyrant with curses," and, in return, his tongue was ordered to be cut out. This order was imperfectly executed, and the loss of half the member is reported to have deprived him of speech. Being afterward persuaded that, if cut close, he might be able to speak intelligently with the root, he submitted to the operation, and subsequently told his own story to Malcolm. These statements were long doubted, but, in 1857, they were fully confirmed by Sir John McNeill, whose inquiries in Persia, where this mode of punishment is common, led to the discovery of many instances of a similar nature. The belief is universal in that country, that excision of the tip of the tongue permanently destroys the power of speech, while its removal at or near the root leaves the victim a chance of regaining the ability to again speak his mind. Surgeons are agreed, however, that, for the purposes of talking, the more there is left of the "unruly member" the better.

But, even after total extirpation of the tongue, persons have been known to retain the faculty of speech without serious impairment. A case of this character is related by Roland, surgeon to the French court in 1630. It is that of a boy who lost his tongue, when six years old, from gangrene, the result of an attack of small-pox. At the time he came under observation, three years later, all that remained of the organ was a slight, double prominence, flattened and attached to the floor of the mouth, extending from the inside of the chin to the oval aperture of the throat. This was composed of muscular tissue, divided by a line, and was like two little muscles, with a furrow between them. When it was pressed, or when the child spoke or swallowed, it swelled, gathered itself up, and retracted from side to side toward its middle, or from one side of the mouth to the other, like two leeches joined together. Roland believed these small bodies to be the remains of some of the muscles ordinarily employed in the movements of the tongue. This child's mouth was anomalous in other respects. The palate was considerably flattened, and the teeth were in a double row, the outer row being the milk-teeth, which had not been shed, and the inner row the permanent teeth, which had come up behind, and pointed inward. Both these conditions the French surgeon attributed to the absence of the tongue, which, by its upward pressure, tends to produce the concavity of the palate, and, by its forward pressure, to force the teeth into a vertical position. The entrance to the pharynx was of an oval shape, and unusually small. The uvula was long and thin, descending almost to the epiglottis, and the tonsils were as large as chestnuts. Notwithstanding the almost complete absence of any thing answering to a tongue, and the additional defects enumerated, the child was able to speak intelligibly. Bonami and Aurran have recorded similar cases in the "Memoirs of the French Academy of Chirurgery."

A still more remarkable example of the retention of the powers of utterance, after loss of the tongue, is that of Margaret Cutting, whose case was brought before the Royal Society of England in 1742, and again in 1747. This girl lost her tongue by what was supposed to be a cancer, when four years old. The disease first appeared in the shape of a small black speck on the upper surface of the tongue, and rapidly eat its way quite back to the root. One day, while the surgeon who had the case in charge was syringing the parts, the tongue dropped out, the girl immediately thereafter, to the great astonishment of those present, saying to her mother: "Don't be frightened, mamma; it will grow again." Three months afterward it was completely healed, with not a vestige of the tongue remaining. At the age of twenty this girl was carefully examined by several competent gentlemen, who report in the 44th volume of the "Philosophical Transactions" as follows, regarding her condition: "We proceeded to examine her mouth with the greatest exactness we could, but found not the least appearance of any remaining part of the tongue, nor was there any uvula. . . . . Notwithstanding the want of so necessary an organ as the tongue was generally supposed to be, to form a great part of our speech, and likewise to be assisting in deglutition, to our great admiration she performed the office of deglutition, both in swallowing solids and fluids, as well as we could, and in the same manner. And as to speech, she discoursed as fluently and as well as others do. . . . She read to us in a book very distinctly and plain, only we observed that sometimes she pronounced words ending in *ath* as *et*, *end* as *emb*, *ad* as *eib*; but it required a nice and strict attention to observe even this difference of sound. She sings very prettily, and pronounces her words in singing as is common."[1]

The inability to speak, after loss or mutilation of the tongue, is sometimes due, not so much to the lack of that organ, as to the state of the sufferer's mind. Like those patients with impaired locomotive powers who, believing they cannot walk, seem to lose the power of will necessary to enable them to try to walk, the person with an imperfect tongue, laboring under the impression that talking is impossible, fails to make the necessary effort, and perhaps would never regain the faculty of speech unless startled into some involuntary exclamation that convinces him of his mistake. An amusing example of this accidental recovery of speech is quoted by Dr. W. Fairlie Clarke from the works of Paré. A rustic who had lost a portion of his tongue, and believed he could not speak, was tickled by a companion while he was in the act of drinking, when, in spite of his mental impression, words burst forth. "He attributed this to the use of the basin that he was holding to his lips; and, having by its means regained faith in his powers of utterance, he always carried a basin about with him, and applied it to his mouth when he wished to speak. . . . The effect of a nervous shock," says Dr. Clarke, "is distinctly seen in a case recorded by the celebrated Dr. Tulp, of a young man sailing in Italy, who was taken by pirates, and carried to Turkey. On account of his refusal to turn Mohammedan, his tongue was cut out. He was dumb for three years, but recovered his speech suddenly one stormy night, when he was terrified by a vivid flash of lightning which was followed by a loud peal of thunder."

In the cases thus far cited, speech was fully developed before loss or mutilation of the tongue occurred, and the other organs, having become perfectly educated, were subsequently able to assume and carry on the function. What is more remarkable still, not only can the tongue be spared after the power of speech has been perfected, but it appears to be quite unnecessary to the development of the faculty. This is shown by a case described by M. de Jussieu, the more interesting parts of whose narrative are given by Clarke, in his

[1] Quoted from W. Fairlie Clarke, "On the Diseases of the Tongue."

work on the "Diseases of the Tongue." The subject was a girl, born tongueless, in a village of Alemtejo, a small province of Portugal. The defect was first made known by her inability to suck, a difficulty that the mother obviated by pressing her breasts, and thus forcing the milk to flow into the infant's mouth while it held the nipple tightly between its lips. This girl was fifteen years old when first seen by Jussieu, who, after two careful and thorough examinations, thus describes the condition of her mouth: "I remarked only a small elevation, in the form of a mamelon, which rose in the middle of the mouth to the height of about three or four lines. This elevation would have almost escaped my observation if I had not assured myself of its existence by touch, for it was scarcely visible. In pressing it with my finger, I felt a sort of movement, of contraction and dilatation, which showed that, although the organ of the tongue was absent, yet the muscles which form it, and which are designed to move it, were present; for there was no hollow under the chin, and I could only attribute the alternating movements which I have described to these muscles. . . . Some persons, perhaps, who doubt the possibility of any one speaking without a tongue, may imagine that in the case of this girl it was not really absent; but that by some natural accident it was adherent to the lower or lateral portions of the mouth. But an inspection will at once remove this impression; for not only is its cavity larger than usual, but at the back the uvula is distinctly visible, and is seen to be more than double the usual length, and also a little thicker than ordinary. It stretches almost to the epiglottis, and forms at the back of the throat two equal rounded openings instead of one; while in other subjects the aperture, though single and larger than the two together in this case, can only be seen by pressing down the base of the tongue."

The function of speech was performed by this girl so distinctly and clearly that no one would have known, without being told, that the tongue was absent. She could clearly pronounce all the letters of the alphabet, as well as separate syllables, and complete sentences. It was observed, however, that some of the consonants, such as *c*, *f*, *g*, *l*, *n*, *r*, *s*, *t*, *x*, and *z*, were pronounced with more difficulty than the other letters, and that, when she had to utter them slowly and separately, the effort required to sound them was shown by bending her head forward, so as to bring her chin nearer to the throat or larynx, thus raising the latter and placing it almost on a level with the teeth.

The *Medical Record* quotes from the Canada *Medical and Surgical Journal*, for March of this year, a case of removal of the tongue and lower jaw of a man aged seventy-one years, in order to get rid of a cancerous mass that extensively involved those parts. Four months after the operation he was brought before the Medico-Chirurgical Society of Montreal; no great amount of deformity was observable, and "speech was restored to some extent, notwithstanding the entire ablation of the chief organ which gave it articulate utterance."

"The singular fact," remarks Jussieu, "of a mouth which could speak though it contained no tongue, ought to convince us that the presence of a tongue is not absolutely essential to speech, since there are other organs in the mouth which contribute to produce articulate sounds, and which can supply the lack of it. The uvula, the nares, the palate, the teeth, and the lips, are all so much concerned in speech, that whole nations are distinguished by the manner in which they make more or less use of one or other of these parts."

THE LATE PROFESSOR JOHN TORREY, M. D., LL. D.

WHEN we proposed to present the portrait of Prof. Torrey in our gallery of eminent scientists, we little thought we should be called to speak of him, in our sketch of his labors, as of the past. For several years his health had been so delicate as to cause anxiety to his family and friends, and he each succeeding winter seemed to be more susceptible to atmospheric changes. Late last winter he had a severe attack of pneumonia, which left him so weak that he was unable to rally, and his death, which was in a measure sudden, occurred on March 10th.

Dr. John Torrey was born in 1796, and was consequently, at the time of his death, in his seventy-seventh year. He was a native of the city of New York, having been born, if we mistake not, in John Street. We recollect hearing him say that, when a boy of some twelve years of age, he was sent of an errand as far as Canal Street, and that he considered it a great hardship to be obliged to go so far into the country after dark. He had in youth a strong liking for machinery, and at one time had the intention of becoming a machinist, but chemistry offered still greater attractions, and he finally concluded to study medicine. His mechanical talent was in after-years of great service to Dr. Torrey, as it enabled him to devise and construct various ingenious forms of apparatus for the illustration of his lectures. While quite a young man he entered the office of Dr. Post, then one of the leading physicians of the city. At that day physicians dispensed their own medicines, and it was the duty of the office-students to prepare the various powders, tinctures, etc., and put up the prescriptions for the patients. The writer has frequently heard Prof. Torrey refer to the great value this experience was to him in after-life, as it gave him an early training in chemical manipulation such as the medical students of the present day rarely acquire.

Dr. Torrey took his degree at the College of Physicians and Sur-

PROF. JOHN TORREY.

geons in New York about the year 1820. He never liked the practiee of medicine, and did not try very earnestly to beeome established in it, and we find him, in 1824, entering upon the duties of Professor of Chemistry at the United States Military Aeademy at West Point. We may here remark that Dr. Torrey's scientifie life was twofold. While he is, perhaps, best known to the world as a botanist, it was as a chemist that he found his remunerative occupation. From the time of his aeceptance of the chair at West Point, up to the day of his death, he was engaged either in teaehing ehemistry or in some position to whieh his profound chemical knowledge adapted him. In 1827 he was called to the ehair of Chemistry in the College of Physieians and Surgeons, which he oeeupied until 1854, and during a portion of this time he was also Professor of Chemistry at Prineeton, where he was assoeiated with Prof. Henry.

In 1854 the United States Assay-Office was established in New York, and Prof. Torrey was appointed assayer, a position of great responsibility, which he held at the time of his death. He was also eonsulting ehemist to the Manhattan Gas Company, and was often engaged as adviser to establishments where ehemical knowledge was required. In early life Prof. Torrey was an enthusiastic mineralogist, and the first and following volumes of *Silliman's Journal* contain important contributions made by him to this science. Before he had received his medieal degree, Dr. Torrey became one of the founders of the New York Lyeeum of Natural History, and was one of the eleven corporators named in the charter of that institution. Early in the history of the Lyceum he was eleeted president, an offiee whieh he filled for several years. In the first number of the Annals we find a botanieal paper from him, and the earlier volumes of this publieation are enriched by some of his most important contributions to seience.

The botanical career of Prof. Torrey commenced while he was yet a student of medieine. His first botanical publieation was "A Catalogue of Plants growing spontaneously within Thirty Miles of the City of New York." This was presented to the Lyeeum in 1817, but was not published until 1819. This work, whieh consists of 100 pages, is now exceedingly rare, and ehanee eopies offered at sales of libraries bring fabulous prices. We find quoted in this catalogue the names of those who were distinguished botanists half a century ago, the author acknowledging aid from Mitehell, Nuttall, Rafinesque, Eaton, Eddy, Le Conte, Cooper, and others. When we consider the youth of the author, barely twenty-one, we must regard this eatalogue as a remarkable performance. Only those who have undertaken similar works can appreeiate the amount of labor neeessary to its produetion, and botanists who go over the same ground at the present day wonder at the completeness of this catalogue. It gives us some idea of the astonishing growth of the city to read in this eatalogue some of the author's favorite loealities, such as "Love Lane," "Bogs near Greenwich," and

"Swamp behind the Botanic Garden," places that have long been covered by paved streets and brick and brown-stone blocks. When we read that one rare plant is found "in sandy fields, above Canal Street," we get a glimpse of what the New York of the author's youth must have been. We have dwelt thus upon this catalogue, as it is the precursor of a list of most valuable botanical publications which we can here only enumerate in chronological order:

1820. "A Notice of Plants collected by Captain N. Douglass around the Great Lakes at the Head-waters of the Mississippi."—(*Silliman's Journal*, vol. iv.)

1823. "Descriptions of some New or Rare Plants from the Rocky Mountains, collected by Dr. Edwin James."—(*Annals of the New York Lyceum of Natural History.*)

1824. "A Flora of the Northern and Middle United States, or a Systematic Arrangement and Description of all the Plants heretofore discovered in the United States north of Virginia." Elliott's "Botany of South Carolina and Georgia" was being published in numbers at the time Dr. Torrey commenced this Flora, which, as he says in his preface, was intended as a "counterpart" to Elliott's work. Like Elliott's work, his was issued in numbers, and the first volume was completed in 1824. But one volume of this work was published, and, as a portion of the edition was destroyed by fire, it is now only rarely to be met with. It contains over 500 pages, and includes the first twelve classes of the Linnæan system, the species being described with a clearness and minuteness and the synonymy elaborated with a care not heretofore displayed in any work upon American botany. It was the first work in which our Northern grasses were treated in a thorough manner, and students of the *Graminaceæ* at the present day find this a most useful work of reference. At an early day the author foresaw that the Linnæan system must be superseded by the natural system of Jussieu. This consideration, together with the loss of a large part of the first volume, led him to abandon the work. In order to supply the immediate wants of students, he prepared a compendium, which gave brief descriptions of the plants contained in the first volume of the Flora and of those which would have been included in the second volume.

1824. "Descriptions of New Grasses from the Rocky Mountains."—(*Annals of the Lyceum.*)

1824. (Joint author with Schweinitz.) "A Monograph of the North American Species of Carex."—(*Annals of the Lyceum.*)

1826. "Compendium of the Flora of the Northern and Middle States"—a full, concise, and compact work, referred to above.

1826. "Some Account of a Collection of Plants made during a Journey to and from the Rocky Mountains in the Summer of 1820, by Edwin P. James, M. D., Assistant-Surgeon United States Army." This paper was read before the Lyceum in 1826, but was not published until 1828. It is a memoir of some 80 pages, and enumerates 481 plants, many of which were new species. This was, up to the date of its publication, the author's most important contribution to science, and is even now frequently referred to by the student of our Western plants. Besides, it has an especial interest, as it was the first American work of any importance in which the arrangement was according to the natural system. The only earlier publication in which the natural system was used being a list by Abbé Correa, of the genera in Muhlenburgh's catalogue, arranged according to the natural orders of Jussieu.

1831. "A Catalogue of North American Genera of Plants, arranged according to the Orders of Lindley's Introduction to Botany." This was published both in a separate form and as an Appendix to an American edition of Lindley's work.

1836. "A Monograph of the Cyperaceæ."—(*Annals of the Lyceum.*)

1837. "New Genera and Species of Plants."

1838. "The Flora of North America, by John Torrey and Asa Gray," was commenced and published in numbers, and at irregular intervals, until the year 1843. Dr. Asa Gray, then a young physician in Western New York, who had already shown great acuteness in his investigations of the flora of the part of the State in which he resided, was happily associated with Dr. Torrey in this great undertaking of publishing a "Flora of North America." The work was suspended with the completion of the "Composition," and for sufficient reasons. Just at this time our Government began to explore its Western territory, soon greatly enlarged by the annexation of Texas and the acquisitions by the war with Mexico. New botanical material accumulated at an astonishing rate, and our chief botanists had to choose between continuing the Flora, and allowing these botanical treasures to pass into other hands. They wisely determined to devote themselves to elaborating the new material, knowing that this work would be contributing to the future flora of North America, which, from the enlarged possessions and more thorough exploration of the older territory, must be taken up *de novo.* Both authors have industriously worked at the collections brought home by the various government and private explorers; those wholly or in large part by Dr. Torrey are here enumerated.

1843. "The Flora of the State of New York," being a portion of "The Natural History of New York." This work is in two large quarto volumes, of over 500 pages each, and illustrated with 161 plates. The descriptions are all redrawn, elaborate, and in a somewhat popular style. It is a most striking testimony to the industry of the author, who, while engaged upon this work, and making important explorations incidental to it, was at the same time discharging his professional duties at the College of Physicians and Surgeons, and at Princeton.

1843. "The Report of Nicollet's Expedition" was published this year, with an appendix by Dr. Torrey, containing an account of the plants collected.

1845. "Catalogue of Plants collected by Lieutenant Fremont in an Expedition to the Rocky Mountains;" and, in the same volume, (Fremont's Report) "Descriptions of some New Genera and Species of Plants collected in Captain J. C. Fremont's Exploring Expedition to Oregon and North California, in the Years 1843 and 1844. By John Torrey and J. C. Fremont."

1848. "Appendix to Emory's Reconnaissance," giving an account of the plants, many of which were new, collected in this expedition.

1852. "Catalogue of Plants collected by Captain Howard Stansbury in his Expedition to the Valley of the Great Salt Lake of Utah."

1853. "Plantæ Fremontianæ; or, Descriptions of Plants collected by Colonel J. C. Fremont in California."—(*Smithsonian Contributions*, vol. vi.)

1853. "On the Darlingtonia Californica, a New Pitcher-plant from Northern California."—(*Smithsonian Contributions, loc. cit.*)

1853. "Observations on the Batis Maritima of Linnæus."—(*Smithsonian Contributions, loc. cit.*)

1853. "Description of Plants collected in Captain Marcy's Exploration of the Red River of Louisiana."

1854. "Botany of Captain Sitgreaves's Expedition to the Zuni and Colorado Rivers."

1855–'60. These years saw the publication of the Reports of the Pacific Railroad Survey. As the reports were not published in the order in which they were written, we enumerate them in the succession in which they occur in the volumes:

Vol. II. "Botany of Captain Pope's Expedition." "Botany of Lieutenant Beckwith's Expedition." "Botany of Captain Gunnison's Survey." In these three memoirs Prof. Asa Gray was joint author.

Vol. IV. "Botany of Whipple's Expedition."

Vol. V. "Botany of Lieutenant Williamson's Report."

Vol. VIII. "Botany of Lieutenant Parke's Expedition."

1859. "Botany of the Mexican Boundary Survey." This is by far the most voluminous of all the Government Reports.

1861. "Botany of Lieutenant Ives's Colorado Exploring Expedition."

We do not include here the contributions of Dr. Torrey to the memoirs of Prof. Gray and others, for which he frequently elaborated genera and families; nor do we enumerate his minor contributions to the sciences.

Nearly all of these memoirs are illustrated by engravings, and some of them profusely so. Dr. Torrey rarely attempted to give the portrait of a plant, leaving that to the professional draughtsman; but in all the sketches showing minute structure—that which gave the illustrations their greatest value to the botanist—his ready pencil found frequent employment. He drew with great neatness and rapidity, and it was his custom to record his observations by means of sketches of remarkable distinctness and accuracy.

For several years subsequent to 1861 he was engaged in herbarium work. His removal to Columbia College, and the disposal of his most valuable collection to that institution, rendered it necessary that the accumulations of years, including numerous typical specimens, should be put into complete order. He entered into the drudgery of assorting, determining, labelling, and putting into the herbarium the mass of unarranged material, with the same industry and zeal that he brought to more congenial work. No other hands than his could have completed this important task, and botanists have reason to be grateful that he was spared long enough to put this, in some respects, the most important herbarium in the country, in proper condition for study and reference.

This work being completed, we find him, though advanced in life, again contributing to his favorite science, and, in 1870, "The Revision of the Eriogoneæ," the joint production of himself and Prof. Asa Gray, was published in the Proceedings of the American Academy of Arts and Sciences. Upon the return of Wilkes's exploring expedition, the botanical collections were divided between Drs. Torrey and Gray, except the Cryptogamia, which were given to several specialists. In this division Dr. Gray took the extra-American share, while those collected upon our Pacific coast were elaborated by Dr. Torrey. Before his memoir could be published, the civil war came on, and stopped all appropriations for such work. Last winter, the proposition to publish was revived, and the last botanical work of Dr. Torrey was to take up, during a rally from his fatal illness, this long-delayed manuscript of the botany of Wilkes's expedition, and prepare it for the press. Although his mind was as clear and his perceptions as acute as ever, his strength was unequal to the task. It will be published as a posthumous work, under the supervision of his intimate friend and associate of many years, Dr. Gray.

This enumeration of his scientific labors would be incomplete without reference to his great work in educating others in science. In the various professorships he held he was always to the students a loved instructor, and many now eminent in science can trace the commencement of their careers to the teachings of Dr. Torrey. Not only in the class-room, but out of it, was his influence constantly exerted, and he was always surrounded by a circle of young men who never came to him in vain for sympathy and encouragement. He gave to such what was better than pecuniary aid, comfort, hope, and help in its best sense. There is many a chemist, now standing high in his profession, who owes his position to his kindly aid, and scarcely a botanist in the country who has not been a recipient of favors from his ever-open hand.

As trustee of Columbia College and of Princeton, he was largely influential in giving scientific studies their proper prominence in these institutions. It was through his influence, more than to that of any other one person, that the "School of Mines" was established. He always took the liveliest interest in its progress, and its ultimate success was to him a source of great gratification.

A few years ago the botanists of New York and vicinity formed an association, to which they gave the name of the Torrey Botanical Club. The club, from small beginnings, became so large that it was thought best that it should become a chartered body, and an act of incorporation was granted, and Dr. Torrey was elected the first president under the charter. This election took place when he was too ill to attend the meeting of the club, and he never assumed the office.

When we come to speak of Dr. Torrey as a man, aside from his scientific work, we feel embarrassed. Were we to say all that we feel, those who did not know him might regard it as extravagant; and, if we are guarded in our expressions, those who knew him well might think we had not done him justice. Soon after his death, one who had known him long said to us, "He is the only man I ever knew of whom it could be said he was truly lovable." "Truly lovable" expresses his character more completely than any other words. However highly we who knew him well may estimate him as a man of science, there is something beyond and beneath this that we admire; and, when we recall Dr. Torrey, it is not as the patient chemist or the acute botanist, but as the friend. It rarely happens to one to possess the peculiar personal attractiveness that was his. There was something about him that invited confidence, and that in advance promised sympathy. When we come to analyze this influence, we are forced to conclude that it was his perfect unselfishness. It was this that drew to him the affections of persons in all walks of life, for there are few who have so many friends as he had, and we doubt that, in dying, he left an enemy behind him. A devoted Christian, he never obtruded his Christianity, but let it appear in his every relation in life. Belonging to a denomination that is by some considered exceedingly strict, he was most charitable for the opinions of those who believed differently; and, while he followed the injunction to "do good to those of the household of faith," he allowed no sectarian lines to shut others out from his sympathy and aid. His faith in Christianity was too deeply grounded to be troubled by any fear that science might lead astray. He followed science with a devotion second only to that to his religion. Knowing that all truths are compatible, and that the researches of the chemist, the geologist, the physicist, or the botanist, can never reveal any thing that will displace God as the author and controller of all, he kept up with the most advanced scientific thought of the day, and remained until the last a devout Christian scientist.

EDITOR'S TABLE.

AIMS OF SCIENTIFIC EDUCATION.

IN a leading article on "The Proper Study of Mankind," the *Nation* recently entered a protest against scientific education; and, as we think it gave its influence to strengthen a current misconception on the subject, it will be in our way to offer a few words of reply.

It is a common opinion, and one which the advocates of the old system of study do all they can to maintain, that Science means merely the physical sciences, which treat of heat, light, electricity, chemical substances, and rock formations; that the value of scientific knowledge consists in its application to arts and industries, by which wealth can be accumulated; and that scientific education simply means the extension of mining, engineering, medical and agricultural schools, while its advocates would be glad to have these overrun the country, and root out all other educational institutions. In other words, the friends of scientific education are constantly charged with being animated by a narrow and sordid utilitarianism. We protest against this view as a gross misrepresentation. Science is not a mere acquaintance with physical things—it is a method of knowing, and is as comprehensive as the phenomena of the world we live in. It is not merely knowledge, it is the most perfect form of knowledge, upon all subjects which it is possible to know. Science is the investigator of Truth—truths of all orders, and by all the mental operations through which truth can be established. The first fact about knowledge is, that it grows; it begins in the common observations and reflections of untaught minds, and gradually develops into clearness, certainty, and precision; is it grovelling utilitarianism to demand that the highest and most perfect forms of knowledge shall be employed in the work of mental cultivation? But few can now be found who will deny that the study of the sciences has great value for mental discipline, and we hazard little in saying that, if pursued systematically, they are capable of giving the mind a training that is more varied and complete than that afforded by any other class of studies. That the influential and representative advocates of scientific education rest its claims upon any grounds of mere selfish utility is not true. No class of men protest more vehemently than they against such low and unworthy motives. They certainly believe in the value of knowledge, and in the eminent value of scientific knowledge; but they hold to a broader and more liberal culture than their adversaries; for, while not rejecting the study of the past, they would enlighten and vivify it by a deeper knowledge of the present. Nor is it true that they are the enemies of literary studies, although the writer in the *Nation* makes them say of the student, "Literature he had better let alone." But they protest against what Dr. Whewell calls the "narrow and enfeebling education" of an exclusive literary culture; and they demand such a restriction of it as will allow room and time for more solid acquisitions and a proper discipline of the faculties that literature neglects. The strongest advocates of scientific education urge increasing attention to the study of English literature; and, more than that, many of them prove, by their fine command of the language, that they have by no means themselves neglected it.

And the writer in the *Nation* not only reaffirms the current error that scientific education can only afford a narrow, utilitarian culture, but his main point is that it breaks down in presence of the higher human interests in which we are all mainly concerned. He declares of its expositors:

"It is assumed, in nearly all that many of them say about education, that it is with Nature only that man has to struggle in the pursuit of happiness; and that, if he can only discover what to eat, drink, and avoid, how mines may best be worked, and crops raised, and distance traversed, and storms foreseen, and the state of the market transmitted, he will have solved the problem of living. . . . It now begins to be discovered, however, that, no matter how successful we may be in wresting her secrets from Nature, or how familiar we make ourselves with her processes, or however conscientiously we may adapt our lives to her requirements, the best scientific education, after all, only half fits us for the battle of life, and for the simple reason that the battle has to be fought not only with hard, inexorable physical surroundings, but with very troublesome and mysterious social surroundings. In other words, in making a career, we have to deal with our brother man as well as with earth and air and water. Let us mine never so successfully, we have to settle with the crowd at the mouth of the shaft before we can carry home our earnings. Let us manufacture never so deftly, we have to establish a rule of distribution before our science or our dexterity does us any good. Let us build railroads as we may, we have to come to an agreement as to who shall work them, and what he shall receive, before they profit us. Heat, and light, and electricity, and steam, are great monarchs, but they cannot raise us out of grovelling barbarism, unless we can come to some understanding with our neighbors as to the ends and modes of living. The study of man, therefore, is really the most important of all studies, and must always continue to be so. Nothing can take its place in any *curriculum*. People must learn how to live in society before they can get any lasting benefit from science, and before they can have and retain any thing worth the name of art; and this they cannot do without observing human nature as it is, and without making themselves acquainted with the past experience of the race. Now, the past experience of the race is found in literature, and languages, and laws, and monuments, or, in other words, in things of which our physicists are apt to make light."

We entirely agree with the writer as to the supreme importance of the study of man and his relations, but we totally dissent from his method of studying them. What we want to know concerning man and society is the laws of their constitution and action, and this it is the proper business of science to ascertain. It is not the office of literature to elucidate natural laws. We have had the literary method in its full power for thousands of years, without dispelling the illusions and obscurities which have shrouded the nature of man and human society. Literature was both incompetent in method and destitute of all the necessary data. Before man and society could be understood, it was necessary first to have correct notions of the workings and order of Nature. Light could only be thrown upon the higher phenomena, as the lower were first explained. To the preliminary work, literature and the literary method contributed absolutely nothing. We owe entirely to modern science that whole series of preliminary revelations concerning the method and operations of Nature, by which it becomes possible to interpret the individual and social phenomena of man. And to science we owe not only the solution of the preliminary problems, upon which the higher depend, but we are also indebted to it for that long and severe discipline, in the quest of truth—that apprenticeship of centuries in the mastery of mental methods—which are necessary to engage with the most difficult of all investigations, the unravelling of the complexities of human nature and the social state. Is all this preparation to go for nothing? Are we to be told that science is incapable of carrying on its own work, and that the agency which was incompetent to begin it is still able to complete it? Undoubtedly "the past experience of the race is found in literature, and languages, and laws, and monuments," and they have their value, which men of science by no means deny; but we have man before us, and society around us, as living and present facts open to immediate inquiry. Why go back to the ages when such a thing as the order of Nature was not even suspected, to get opinions concerning the constitution of things which are displayed before our very eyes. It is true that the study of the past can aid in the understanding of the present; but it is a deeper truth that the study of that which comes within the range of actual experience is the only key to the understanding of the past—Science must be the interpreter of History. The nature of man; the laws of his physical, mental, and moral constitution; their interdependence and reactions; and how he has come to be what he is: the nature of social aggregations; the natural laws by which they are regulated, and how they have come to be what we see them—are strict and legitimate scientific questions, and are no more to be determined by the literary method than the constitution of the sun or the origin of species. Biology, psychology, ethnology, and anthropology, are the names of branches of knowledge, imperfect indeed, but firmly established, which have been created by modern science, and which have already thrown a flood of light upon the nature of man. The scientific knowledge thus obtained is also the only indispensable basis for understanding the constitution and course of human society; and, if the reader cares to understand *how* essential one of those sciences is to the proper understanding of social phenomena, we recommend him to read the article in the present number of the MONTHLY on the bearings of biology upon sociological studies.

We have seen that the assumption of the writer in the *Nation*, that science is confined to the lower sphere of physical phenomena, is altogether gratuitous; and that man and society, if they are ever to be understood, must in future be mainly studied by the method of science which seeks for the establishment of natural laws. On what ground, then, can it be pretended that the study of man and human interests does not fall within the compass of scientific education? The writer seems to take it as a foregone conclusion that science has nothing to do with "the proper study of mankind;" yet scientific education has been long urged by its ablest advocates upon the very ground that it has every thing to do with it. Mr. J. S. Mill, although no partisan upon this question, explicitly denies the position taken by the *Nation*. In his celebrated address at the University of St. Andrew's, in 1867, he said: "Scientific education, apart from professional objects, is but a preparation for judging rightly of man and of his requirements and interests;" and he advocated compendious methods of classical study to allow more science in the universities, with a view to this very object.

In an article published in an English review in 1859, discussing the worth and claims of different kinds of knowledge, and which is one of the most powerful pleas for scientific education that have yet appeared — an article which was translated into half a dozen European languages, and which has been republished in all shapes and a score of times in this country—the claims of scientific education were placed upon the distinctive ground of its bearing upon the highest human interests. We extract a closing passage:

"Thus, to the question with which we set out—What knowledge is of most worth? —the uniform reply is—science! This is the verdict on all the counts. For direct self-preservation, or the maintenance of life and health, the all-important knowledge is —science. For that indirect self-preservation which we call gaining a livelihood, the knowledge of greatest value is—science. For the due discharge of parental functions, the proper guidance is to be found only in—science. For that interpretation of national life, past and present, without which the citizen cannot regulate his conduct, the indispensable key is—science. Alike for the most perfect production and highest enjoyment of art in all its forms, the needful preparation is still—science. The question which at first seemed so perplexed has become, in the course of our inquiry, comparatively simple. We have not to estimate the degrees of importance of different orders of human activity and different studies as severally fitting us for them; since we find that the study of science, in its most comprehensive meaning, is the best preparation for all these orders of activity. We have not to decide between the claims of knowledge of great though conventional value, and knowledge of less though intrinsic value; seeing that the knowledge which we find to be of most value in all other respects is intrinsically most valuable; its worth is not dependent upon opinion, but is as fixed as is the relation of man to the surrounding world. Necessary and eternal as are its truths, all science concerns all mankind for all time. Equally at present, and in the remotest future, must it be of incalculable importance for the regulation of their conduct, that men should understand the science of life, physical, mental, and social: and that they should understand all other science as a key to the science of life."

CLASSICS AS A PREPARATION FOR ENGLISH.

The readers of the Monthly may recollect that, in his article in the April number, Mr. Spencer criticised the position taken by Matthew Arnold in regard to the needs of English culture. Mr. Arnold is a great admirer of the French Academy, which, he says, was established "to work, with all the care and all the diligence possible, at giving sure rules to our (the French) language, and rendering it pure, eloquent, and capable of treating the arts and sciences," and he thinks something of the kind would be of great service in England. Mr. Spencer pinted out the inefficiency and absurdity of such an attempt at supervision, and prepared a note to the article, which was not printed with it. We insert it here, as it has both a personal interest and a significance in relation to classical studies, as a preparation for English:

"Before leaving the question of Academies and their influences, let me call attention to a fact which makes me doubt whether as a judge of style, considered simply as correct or incorrect, an Academy is to be trusted. Mr. Arnold, insisting on propriety of expression, and giving instances of bad taste among our writers, due, as he thinks, to absence of Academic control, tacitly asserts than an Academy, if we had one, would condemn the passages he quotes as deserving condemnation, and, by implication, would approve the passages he quotes as worthy of approval. Let us see to what Mr. Arnold awards his praise. He says:

'To illustrate what I mean by an example. Addison, writing as a moralist on fixedness in religious faith, says:

"Those who delight in reading books of controversy do very seldom arrive at a fixed and settled habit of faith. The doubt which was laid revives again, and shows itself in new difficulties; and that generally for this reason—because the mind, which is perpetually tossed in controversies and disputes, is apt to forget the reasons which had once set it at rest, and to be disquieted with any former perplexity when it appears in a new shape, or is started by a different hand."

'It may be said, that is classical English, perfect in lucidity, measure, and propriety. I make no objection; but in my turn, I say that the idea expressed is perfectly trite and barren,' etc., etc.

"In Mr. Arnold's estimate of Addison's thought I coincide entirely; but I cannot join him in applauding the 'classical English' conveying the thought. Indeed, I am not a little astonished that one whose taste in style is proved by his own writing to be so good, and who to his poems especially gives a sculpturesque finish, should have quoted, not simply without condemnation but with tacit eulogy, a passage full of faults. Let us examine it critically, part by part.

"How shall we interpret into thought the words 'arrive at a . . . habit?' A habit is *produced.* But 'arrival' implies, not *production* of a thing, but coming up to a thing that preëxists, as at the end of a journey. What, again, shall we say of the phrase, 'a fixed and settled habit?' Habit is a course of action characterized by constancy, as distinguished from courses of action that are inconstant. If the word 'settled' were unobjectionable, we might define habit as *a settled course of action;* and, on substituting for the word this equivalent, the phrase would read 'a fixed and settled settled course of action.' Obviously the word *habit* itself conveys the whole notion; and, if there needs a word to indicate degree, it should be a word suggesting *force*, not suggesting *rest.* The reader is to be impressed with the *strength of a tendency* in something active, not with the *firmness* of something passive, as by the words 'fixed and settled.' And then why 'fixed *and* settled?' Making no objection to the words as having inapplicable meanings, there is the objection that one of them would be sufficient: surely that which is fixed must be settled. Nor are these all the imperfections in this short sentence. The habit referred to is the habit of *believing;* and to call it the habit of *faith* is to imply that the words *faith* and *believing* are synonymous.

"Passing to the next sentence, we are arrested by a conspicuous fault in its first clause—'The doubt which was laid *revives again.*' To revive is to live again; so that the literal meaning of the clause is 'the doubt which was laid lives again again.' In the following line there is nothing objectionable; but at the end of it we come to another pleonasm. The words run: 'and that generally for this reason, because the mind. . . .' The idea is fully conveyed by the words, 'and that generally because the mind.' The words 'for this reason' are equivalent to an additional 'because.' So that we have here another nonsensical duplication. Going a little further there rises the question — Why 'controversies *and* disputes?' 'Dispute' is given in dictionaries as one of the synonymes of 'controversy;' and though it may be rightly held to have not quite the same meaning, any additional meaning it has does not aid, but rather interrupts, the thought of the reader. Though, where special attention is to be drawn to a certain element of the thought, two almost synonymous words may fitly be used to make the reader dwell longer on that element, yet, where his attention is to be drawn to another element of the thought (as here to the *effect* of controversy on the mind), there is no gain, but a loss, in stopping him to interpret a second word if the first suffices. One more fault remains. The mind is said 'to be disquieted with any former perplexity when it appears in a new shape, or is started by a different hand.' This portion of the sentence is doubly defective. The two metaphors are incongruous. Appearing in a shape, as a ghost might be supposed to do, conveys one kind of idea; and started by a hand, as a horse or a hound might be, conveys a conflicting kind of idea. This defect, however, is less serious than the other; namely, the unfitness of the second metaphor for giving a concrete form to the abstract idea. How is it possible to 'start' a perplexity? 'Perplexity,' by derivation and as commonly used, involves the thought of entanglement and arrest of motion; while to start a thing is to set it in motion. So that, whereas the mind is to be represented as enmeshed, and thus impeded in its movements, the metaphor used to describe its state is one suggesting the freedom and rapid motion of that which enmeshes it.

"Even were these hypercriticisms, it might be said that they are rightly to be made on a passage which is considered a model of style. But they are not hypercriticisms. To show that the defects indicated are grave, it only needs to read without its tautologies one of the sentences thus: 'The doubt which was laid revives, and shows itself in new difficulties; and that generally because the mind which is perpetually tossed in controversies is apt to forget the reasons which had once set it at rest,' etc., etc. Omitting the six superfluous words unquestionably makes the sentence clearer—adds to its force without taking from its meaning. Nor would removal of the other excrescences, and substitution of appropriate words for those which are unfit, fail similarly to improve the rest of the passage.

"And now is it not strange that two sentences which Mr. Arnold admits to be 'classical English, perfect in lucidity, measure, and propriety,' should contain so many defects: some of them, indeed, deserving a stronger word of disapproval? It is true that analysis discloses occasional errors in the sentences of nearly all writers—some due to inadvertence, some to confusion of thought. Doubtless, from my own books examples could be taken; and I should think it unfair to blame any one for now and then tripping. But, in a passage of which the diction seems 'perfect' to one who would like to have style refined by authoritative criticism, we may expect entire conformity to the laws of correct expression; and may not unnaturally be surprised to find so many deviations from those laws.

"Possibly, indeed, it will be alleged that the faults are not in Addison's English, but that I lack the needful æsthetic perception. Having, when young, effectually resisted that classical culture which Mr. Arnold thinks indispensable, I may be blind to the beauties he perceives; and my undisciplined taste may lead me to condemn as defects what are, in fact, perfections. Knowing absolutely nothing of the masterpieces of ancient literature in the original, and very little in translation, I suppose I must infer that a familiarity with them equal to Mr. Arnold's familiarity would have given me a capacity for admiring these traits of style which he admires. Perhaps redundance of epithets would have afforded me pleasure; perhaps I should have been delighted by duplications of meaning; perhaps from inconsistent metaphors I might have received some now unimaginable gratification. Being, however, without any guidance save that yielded by mental science—having been led by analysis of thought to conclude that, in writing, words must be so chosen and arranged as to convey ideas with the greatest ease, precision, and vividness; and having drawn the corollaries that superfluous words should be struck out, that words which have associations at variance with the propositions to be set forth should be avoided, and that there should be used no misleading figures of speech; I have acquired a dislike to modes of expression like these Mr. Arnold regards as perfect in their propriety. Almost converted though I have been by his eloquent advocacy of culture, as he understands it, I must confess that, now I see what he applauds, my growing faith receives a rude check. While recognizing my unregenerate state, and while admitting that I have only psychology and logic to help me, I am perverse enough to rejoice that we have not had an Academy; since, judging from the evidence Mr. Arnold affords, it would, among other mischievous acts, have further raised the estimate of a style which is even now unduly praised."

"*TOO MATERIALISTIC.*"

THE *Buffalo Commercial Advertiser* commends THE POPULAR SCIENCE MONTHLY, but thinks that "it tends somewhat to a too materialistic nature in certain of its articles." The *Advertiser* is not alone in its objection; other newspapers, both religious and secular, frequently remind us that our pages are "too materialistic." As there seems to be so general an agreement upon this point, it is to be presumed that the subject is perfectly understood, and we have only to regret that our critics are not more explicit, and do not tell us exactly what they mean by *materialism*, and point out just how far we should go in that direction. If we are "too materialistic," how materialistic is it proper we should be?

By materialism can hardly be meant in this case that speculative doctrine which denies spirit, and affirms that every thing is matter, because we have not gone into that question at all, and it is hardly to be expected that our monitors would tolerate that in any degree. It must, therefore, be meant that we give undue prominence to material subjects and material explanations of things; but the importance they assume is certainly not our fault, for we are responsible neither for the existence of matter nor for the part it plays in the economy of the universe. Matter—"mere gross, brute matter"—may be very undignified and objectionable stuff, and, if some people had been consulted at the creation, perhaps it would have been left out altogether. But it certainly was not left out; it is here, whatever it may be, the foundation of existence, and not to be got rid of. We are all made of it; and each of us has to add several pounds daily to his personal stock, upon penalty of death for non-compliance. The mass of mankind, moreover, are doomed to work in it, shaping and transforming it in a thousand ways all their lives long. The very instruments and conditions of all our feelings, enjoyments, and thoughts, are material, while the Divine Power employs matter as the great medium of working out the laws of being and the harmonies of existence. It was said by Plato that God ever geometrizes; but it is still a profounder truth that God ever *materializes*. We, therefore, dodge the criticism about being "too materialistic," and leave our newspaper friends to settle their differences with the higher powers. Science is a knowledge of the laws of Nature, and nothing remains for us but to take Nature as we find it; and, as matter is mixed up with every thing, we cannot ignore it. There have been systems of thought in which the consideration of matter was allowed no place, but they have been futile and fruitless; science, on the other hand, is a system of thought which respects the order of things, and includes matter as the first and constant object of inquiry; and it has opened a new realm of truth, and changed the course of human affairs. After the world had been long dominated by philosophies that were full of contempt for matter—philosophies that were espoused by theology and accredited in the great seats of learning—it was not surprising that science, which declared matter to be an excellent thing, and quite fit to be studied, should have been denounced and resisted; but it *is* surprising that after science has made an intellectual epoch, and created a new and nobler future for humanity by the study of the divine laws as embodied in matter, there should still be those who mumble the exploded prejudices of the past, and make themselves miserable about the "too materialistic" tendencies of modern thought. Read Papillon's article in the present number of the MONTHLY, and see what "matter" means in the light of recent science.

And, speaking of materialism, here comes the London *Spectator*, with more talk upon the subject. This journal affects philosophy, and, for years, has been in the habit of branding with opprobrious epithets doctrines it did not happen to like. It recently tried to fasten the imputation of materialism upon Mr. Douglas Spalding, on account of his psychological views; but that gentleman repelled the charge, and, apparently in much confusion over the subject, the *Spectator* now formally asks, "What is modern materialism?"—a question which it might better have settled, for its own guidance, some time ago. And the answer which the *Spectator* gives to its own question is certainly extraordinary. In the first place, it informs us what materialism is *not;* and, strange to stay, it declares that a belief in the materiality of the soul—that its qualities are physical, visible, or tangible, instead of spiritual—is not materialism. The editor says: "It is not properly, we think, materialism to believe, as some very eminent thinkers, and some very eminent and (in their day) orthodox ecclesiastics have believed, that the soul of man is a physical entity, existing only at some particular point of space." On the other hand, the *Spectator* affirms that the pure idealist, who goes so far as to deny the existence of matter, and to resolve all things into immaterial or spiritual agencies, may yet be a materialist. Hence, according to this oracle, he who believes in nothing but matter need not be a materialist; and he who believes in nothing but spirit may still be liable to the reproach of materialism. But, if materialism has nothing to do with the question of matter and spirit, in what does it consist? Why, according to the *Spectator*, it consists in believing that the universe unfolds from a lower into a higher state, and "that the higher order of phenomena are strictly dependent on the lower." Nor does it make any difference if the universe is held to have been caused and to be governed by a Creative Spirit; if that government proceeds by the method of a gradual unfolding from the lower to the higher, he who believes it is a materialist. And so, in the last exigency of polemics, an obnoxious term is wrenched from its strict and long-sanctioned significance to be used simply as a vehicle of opprobrium. The *Spectator* would have been equally honest and less absurd if it had compressed its article into two lines as follows: "What is modern materialism? A dirty label to be plastered upon the evolutionists."

LITERARY NOTICES.

Prehistoric Races of the United States of America. By J. W. Foster, LL. D. Chicago: S. C. Griggs & Co., 1873, pp. 415, price $5.00.

In briefly referring last month to the sudden and lamented death of Dr. Foster, we mentioned that he had just completed a new work on the prehistoric American races. A careful examination of the book has satisfied us that it is one of the most interesting and important contributions to American archæology that have yet appeared, and will take rank with the leading treatises upon the general subject by European archæologists. We had thought of making some extracts from the volume, but it is so full of interest, from beginning to end, as to make selection perplexing, and were it not for the restraints of copyright we should be tempted to run the whole work through The Popular Science Monthly, as it contains just that kind of information, in clear, compressed, and intelligible form, which is adapted to the mass of readers. Although drawing upon various authentic sources for his facts, Dr. Foster was very far from being a mere compiler. He had an enthusiastic interest in the question, and pursued it by direct observation and extensive original inquiries. The author explains how he was attracted to the investigation, in the opening passage of his preface. He says: "In early manhood, when, for the first time, I gazed upon the works of that mysterious people known as the mound-builders, my mind received a class of impressions which subsequent years have failed to efface. These works are in the vicinity of Newark, Ohio; and, although not the most stupendous, are the most elaborate in the whole series. It was a bright summer's morning, and the sunlight, streaming through the opening of the dense canopy of foliage above, fell upon the ground in flickering patches. A slumberous silence filled the air; and I confess that, as I traced out the labyrinthine system of earthworks here displayed, with its great circles and squares, its octagons, gate-ways, parallel roads, and tumuli, the whole spread over an area of several square miles, and as I speculated upon the purposes of their construction, and on the origin and extinction of the people by whom they were reared, I was profoundly impressed."

The first chapter of the work gives an excellent summary of the general argument on the antiquity of man, as illustrated by European evidences. The second chapter discusses the same question, on the basis of evidence furnished in the United States. Chapter III. opens the question of the mound-builders, and the geographical distribution of their works; and the fourth chapter treats of shell-banks and shell-heaps, and the character of the crania found associated with them. Chapters V., VI., and VII., amplify the discussion of the mound-builders, their enclosures, their arts and manufactures, and the character of their ancient mining. The cranial and anatomical characters of the mound-builders are dealt with in Chapter VIII., while Chapter IX. considers their manners and customs, on the basis of ethnic relations. The problem of the old American civilizations is here entered upon, preparatory to the question, "Who were the mound-builders?" considered in Chapter X. Chapter XI. summarizes the discussion of the unity of the human race; and Chapter XII. closes the work, by treating of chronometric measurements, as applied to the antiquity of man. The whole exposition is condensed into 400 pages, and the publishers have done their part, in the fine execution of the engravings, and the beautiful typography of the book.

Foods. By Edward Smith, M. D., LL. B., F. R. S. New York: Appletons, 1873, pp. 485, price $1.75.

When the editor of this periodical was in Europe, in 1871, arranging with authors to write for the International Scientific Series, he was assured, by good authority, that the ablest man in England to treat the subject of foods was Dr. Edward Smith. This gentleman had made important researches into the character and physiological effects of aliments, and his results were accepted among men of science as of great value. He was a Government Inspector of Dietaries, and had published several works upon Food and Diet. His services were secured for the undertaking, and the little treatise he has produced shows that the choice of a writer on this important subject was most fortunate, as the book is unquestionably the clearest and best-digested compend of the Science of Foods that has appeared in our language.

The excellent work of Pereira was published thirty years ago, and nothing better has been issued during the past generation; but the advances in our knowledge of the subject have been so great that it is now out of date, and is but rarely referred to. Dr. Smith's book is not only scientific but practical: besides explaining the nature and properties of foods, as determined by the chemist, he shows how they are altered in taste and digestibility by the operations of the kitchen; and presents the information in so simple and intelligible a form, that it may be apprehended by everybody. Dr. Smith's "Foods" is emphatically a book for the people; not a mere receipt-book, although it contains many excellent directions for the preparation and use of aliments, but a summary of facts and principles for those who desire to understand the subject. His classification is simple and comprehensive. The term *foods*, as he uses it, embraces all forms of matter that are introduced into the living system to carry on the vital processes, and his leading divisions are into solid foods, liquid foods, and gaseous foods. Part I., treating of solid foods, takes up first animal foods, which are grouped as nitrogenous and non-nitrogenous, and the vegetable foods are then considered under the same groups. Part II. treats of liquids—water, milk, tea, coffee, and the various beverages, including alcohols. Part III. treats of atmospheric air, from the alimentary point of view. As it costs nothing, requires no cooking, and is not passed into the stomach for digestion, air is not generally included among foods; but, as it is more necessary to the vital processes than any other substance, and is honored with a special channel for introduction into the system, and is liable to such variation of quality as profoundly to affect the health, its treatment was necessary to give completeness to the plan of the work, and no portion of it will be found more interesting or important than this. Dr. Smith has enriched his volume by a series of graphical diagrams, which present to the eye the effect of various alimentary substances upon the pulse and respiration. This method of physiological illustration is of great value, and has been long in use among scientific men, as it brings into pictorial view, so as to be quickly comprehended and easily remembered, the results of long trains of investigation. This is the first time that the graphic method of illustration has been applied to this subject, for purposes of popular instruction. A little careful attention will be required at first, to get familiar with the mode of illustration, but for this the result will be found amply compensating.

Arrangements have been made for the translation of the International Scientific Series into the Russian language, and the works are all to be published in St. Petersburg. Negotiations are also pending for the reproduction of the series in the Italian language. When this is done, each author will be read in six countries, and have payment for his book from six publishers. The works of Prof. Bain on "Mind and Body;" of Dr. Pettigrew, on "Animal Locomotion;" of Balfour Stewart, on "The Conservation of Energy;" of Prof. Marey, on "The Animal Machine;" of Herbert Spencer, on "The Study of Sociology;" of Prof. Amos, on "The Science of Law;" and of Dr. Carpenter, on "Mental Physiology," are now all in press, and will be soon issued, and are to be rapidly followed by other English, German, French, and American works, now in course of preparation.

Second Book of Botany; a Practical Guide to the Observation and Study of Plants. By Eliza A. Youmans. Pp. 310, 422 cuts. Price $1.50. New York: D. Appleton & Co.

This volume is a continuation of the method adopted by Miss Youmans in the "First Book of Botany," published three years ago; and its peculiarity is that it enforces the direct and systematic study of plants themselves. Her object is to make the study of Nature a means of mental cultivation—an end which can only be gained by familiarity with the objects of Nature, and for this our schools, as at present managed, make no suitable preparation. In her Introduction Miss Youmans says: "Our plan of general education includes not a single subject that can secure the mental advantages arising from the direct and systematic study of Nature. We do a great deal in the way of 'mental discipline,' but the order and truth of things around us are not allowed to contribute to it. We train the faculty of calculation and drill the memory in lesson-learning; but the realities of Nature find no place in our schools, as means of mental unfolding, for training in observation, and for working the higher faculties of reason and judgment, upon natural things. In short, for calling out the more important powers of the mind by actual exercise upon the objects of surrounding experience, our educational system makes no provision whatever. Neither reading, writing, arithmetic, grammar, nor geography, brings the mind into contact with Nature at all; and even the sciences of physics, chemistry, physiology, and botany, are usually acquired from books, and with so little regard to the real objects of which they treat, that, as means of mental improvement, they are of very slight service."

Believing that botany has special and preëminent claims to be introduced into all schools, as a means of training the faculties of observation and reason upon actual phenomena, Miss Youmans has shaped her method entirely to the attainment of this end. She holds that "like arithmetic, botany is only to be acquired by first mastering its rudiments. And as in arithmetic the student is compelled to exercise his mind directly upon numbers, and work out problems for himself, so in botany, if worth pursuing at all, it should be studied in its actual objects. The characters of plants must become familiarly known by the detailed and repeated examination and accurate description of large numbers of specimens. The pupil must proceed step by step in this preliminary work, digesting his observations, and making the facts his own, until he becomes intelligent in regard to the common varieties of plant-forms and structures. It is because the text-books of botany hitherto in use fail to provide for and to enforce this thoroughness of introductory study of the characters of plants—fail in the very groundwork of the subject—that the present plan of study has been prepared."

Miss Youmans's books, therefore, bear the same relation to the vegetable kingdom that an art-gallery "guide" bears to a collection of pictures: in connection with them it is valuable and important; apart from them, of little use. To those who wish to *read* botany, or to acquire it by the usual method of lesson-learning, her books will be of small service; but, to such as desire to know the science itself in its facts and principles at first hand, and to become so intelligent in regard to vegetable forms that they can read them as they walk in the fields, like printed pages, the method of study that she has arranged will be invaluable. The object that she wishes to secure being mainly educational—the cultivation of independent observation and reason, as applied to objects of experience—she insists that the study must be commenced early, while the childish mind is in its perceptive stage and peculiarly alive to external things. The First Book is therefore adapted to young children and beginners, and deals only with those readily-observed characters of plants which can be examined with the naked eye. The Second Book begins where the First left off, and goes more thoroughly into the work; the use of magnifying-glasses and microscopes is now commenced, and observation becomes careful and complete. The schedule system is carried out in its application to the flower, and "the pupil is introduced to the leading principles by which plants are arranged, and set to making groups of those that most nearly resemble each other in important characters. He is here called upon to do his own thinking, and to form opinions as to the amount of resemblance between different plants. He has to decide whether a certain group of characters presented by this specimen is most like one or another group presented by other plants, and this leads on to the comparison and estimate of the relations of different groups with each other. It is thus that the discipline of the judgment and reason begins to be secured at an early stage of the study, and is continued with more and more completeness as it goes on."

A great deal is said by thoughtful educators about the need of the more direct and thorough study of Nature, but the difficulty has hitherto been, how to make it generally possible and practicable. These little Books of Botany show how it may be done, and provide for the doing of it. "They are guides to self-education, and are adapted for use in school or out, by teachers and mothers, whether they know any thing of the subject or not, and by pupils without any assistance at all." They set the pupil to work, guide him in his course, and bring him face to face continually with difficulties which it will require the exercise of independent judgment to deal with. Mistakes will of course be made, and effort will be necessary to correct them, but this is the sole condition on which the judgment of things is to be educated. The value of the study of natural history classifications as a means of higher mental discipline—not in books, but in the objects themselves which illustrate them—has been long recognized, and botany unquestionably affords the best facilities for obtaining it. Upon this point Miss Youmans remarks: "Its discipline is corrective of the most common defects of education, and is eminently applicable in forming judgments upon the ordinary affairs of life. Carelessness in observation, looseness in the application of words, hasty inferences from partial data, and lack of method in the contents of the mind, are common faults even among the cultivated, and it is precisely these faults that the study of botanical science, by the method here proposed, is calculated to remedy. That the habit of systematic arrangement, in which the study of botanical classification affords so admirable a training, is equally valuable in methodizing all the results of thought, is testified to by one of the most intellectual and influential men of our time, Mr. John Stuart Mill. He was a regular field botanist, and cultivated the subject with a view to its important mental advantages; and his great work on logic took a form which could not have been given it if the author had not been a working naturalist as well as a logician. In the second volume of his "System of Logic" Mr. Mill says:

"Although the scientific arrangements of organic Nature afford as yet the only complete example of the true principles of rational classification, whether as to the formation of groups or of series, these principles are applicable to all cases in which mankind are called upon to bring the various parts of any extensive subject into mental coördination. They are as much to the point when subjects are to be classed for purposes of art or business, as for those of science. The proper arrangement, for example, of a code of laws, depends on the same scientific conditions as the classifications in natural history; nor could there be a better preparatory discipline for that important function than the study of the principles of a natural arrangement, not only in the abstract, but in their actual application to the class of phenomena for which they were first elaborated, and which are still the best school for learning their use."

The Sanitarian. A Monthly Journal, edited by A. N. Bell, M. D. New York: A. S. Barnes & Co. $3.00 per annum.

The sanitary question is now uppermost in the public mind, and it is gratifying to see that the discussion of it is not going to be kept as a "mystery" in the medical profession. Every human being is concerned in this matter; and, if sanitary science has any suggestions to make, they must be made directly to the people themselves. This is what the periodical before us aims to do, and this it is doing well. The paper in the August number on the ventilation of the public schools of this city ought to be printed separately and placed in the hands of all the commissioners, trustees, inspectors, superintendents, and other officers connected with the schools—not excepting the janitors. The same number contains also the following articles: Cholera stamped out; Animal Refuse of Large Cities; Defective Drainage; Action of Tea on the Human System; Cholera; Morbid Effects of Alcohol; the Public Health; Editor's Table; Book Notices.

MISCELLANY.

Fish-Culture in New Zealand.—Last January a large quantity of salmon-eggs from English waters was shipped to New Zealand. They would reach their destination in 112 days, but it was a question whether they would bear so protracted a journey, though carefully packed and surrounded by ice. To determine this question, four boxes of ova, packed after the same manner as those sent to New Zealand, were deposited at the office of a London ice company. After the lapse of 112 days, these boxes were opened, and the temperature was then found to be 38° Fahr. "In one of the boxes," writes Mr. Buckland, "the eggs nearly all contained living fish; in another they were 'blind,' that is to say, no embryo could be seen in them. In all the boxes there was a certain percentage of eggs which had turned quite white. Some of these white eggs presented a curious appearance—namely, a spot exactly the color of a strawberry, which covered a third of the surface of the egg."

The experiment was on the whole satisfactory, and proves that salmon-eggs may be kept in a healthy condition for 112 days or longer. It is still a question, however, whether the rivers of New Zealand are suited for the cultivation of salmon. Some years ago 1,200 trout-ova were shipped to Victoria, and recently Mr. Buckland received from that colony a trout weighing 7½ lbs. If salmon thrive equally well in Australasian waters, this essay in "practical natural history" will be productive of immense benefits to the British colonies in the South Pacific at no distant day.

New Theory of Boiler Explosions.—A late number of the *American Artisan* has a paper by Dr. L. Bradley, on "The Dissociation of Water by Heat as a Cause of Boiler Explosions," in which the author very well shows that such accidents are in many cases produced, not by tension of steam, but by the explosion of oxyhydrogen gas. Dr. Bradley in the first place states very clearly the history of the law of dissociation, or the separation of a compound body into its elements by the force of heat. Under atmospheric pressure the two elements of watery vapor, viz., oxygen and hydrogen, are dissociated at 1,298° Fahr. "If, therefore," says the author, "we heat a bar of iron to fully 1,298°, and place it over a globule of water upon an anvil, a blow with a hammer will elicit the detonation of a rifle; I have repeated this experiment often. The elements of the water dissociate by the heat, and instantaneously recombine in cooling, causing the detonation."

The degree of dissociation, as of evaporation, depends on the pressure: under four atmospheres (60 lbs.), the heat required for dissociation is 1,870°. But the question arises, If the vapor dissociates at these temperatures, why do not the gases instantaneously combine and detonate? The reason is plain: in the boiler the atoms at once become mixed with a volume of steam sufficient to render them inexplosive.

The condition requisite for the generation of explosive gas in a boiler is that vapor be in contact with a surface heated to 1,298°, or higher, according to the pressure, as we have seen. Now, this condition may occur in a boiler filled with water, owing to the property which that liquid possesses of assuming the spheroidal shape when in contact with a highly-heated surface. "It is, therefore, not difficult to conclude," says the author, "that, in case of very heavy firing, a thin film of vapor may form between the water and the boiler, and, when this is once formed, the heating of the boiler would be so rapid that nothing but the cooling process of dissociation, which would then commence, could save it from completely burning through."

Explosion would then occur whenever—
1. The oxyhydrogen gas, as compared with the steam, *rises* to the explosive proportion; or, 2. When the steam, by condensation, *fails* to the explosive proportion. To make explosion possible, the proportion of oxyhydrogen gas to vapor must be at least as 1 to 7.

Scientific Education in England.—Sir Josiah Mason, a manufacturer of Birmingham, is about to found a scientific college in that town on a most liberal scale. It is intended to afford thorough systematic scientific instruction, specially adapted to the practical, mechanical, and artistic requirements of that great centre of manufacturing industry. Systematic instruction is to be given in mathematics; abstract and applied physics; chemistry, theoretical, practical, and applied; the natural sciences, especially geology and mineralogy, with their application to mines and metallurgy; botany and zoology, with special application to manufactures; and physiology, with special reference to the laws of health. The English, French, and German languages will be taught, but mere literary instruction is excluded. No principal, professor, teacher, or other officer of the college, is ever to be called upon to make any "declaration as to, or submit to any test whatever of, his religious opinions," and the institution is to admit all persons "without distinction of age, class, creed, race, or sex," to the popular lectures; while the regular course will be open to qualified persons of all classes, "especially the more intelligent youth of the middle class." This *Nature* calls "one of the most princely gifts yet made to posterity in England by one of her wealthy sons."

The Hotchkiss Revolver-Cannon.—Some trials were recently made, says the *Revue d'Artillerie*, at the Satory Polygon, with a revolving cannon, invented by Mr. Hotchkiss, and intended for the Italian Government. The special object of these experiments was to ascertain the mechanical value of this engine. This new arm (whose calibre is 1½ inch) differs essentially from all other mitrailleuses hitherto brought before the public, particularly in this, that it discharges a small cast-iron shell with percussion fuse, the effects of which may be formidable at distances relatively considerable.

We will, at another time, present a complete description of this gun, but for the present must content ourselves with giving some details of the ammunition employed. This consists of a cartridge with shell attached. The cartridge proper consists of a soldered tube of tin, with one end closed to form a cup. This closed end is reënforced, within and without, by two iron caps, and fastened with three rivets to a broader iron plate, which forms the true base of the cartridge, bears the pressure of the gases, and affords a grip to the extractor. The percussion cap is fixed in the centre of this iron plate. The cartridge will hold 3½ ounces of powder, with space for a thick felt wad between the latter and the projectile. The charge of powder employed at Satory was only 2⅝ ounces, the unoccupied space being filled with two disks of brown paper, laid over the powder and covered with wadding. The shell, which has a total length of 2½ calibres, has a jacket of latten covering a portion of its length, with grooves answering to the riflings of the gun. Its weight is 17½ ounces, and it contains a charge of 1⅝ ounce of powder. The whole cartridge, charged and primed, weighs 28⅛ ounces.

The shell does not appear to be held tightly enough in the cartridge-case; it can be detached by the hand with but little trouble, and there is reason to fear lest, when charged cartridges are transported in boxes, the shells may be separated from their sockets.

To obviate all accidents, the revolver-cannon was set *en batterie* at about 100 metres, or 328 feet, from the butte, the shells being charged and provided with thin percussion fuses. At first the exploded cartridges, when withdrawn from the cannon, were not at once dropped by the extractor; but this slight defect was in a few minutes remedied, and, during the remainder of the experiments, there was no further difficulty in working the piece. The cartridges were greased before being used.

They suffered no injury from the discharge, and could be recharged and used over and over again. One had opened along the soldering, but had not been rent, nor had any gas escaped. It could be used again, on being soldered anew. Only one cartridge missed fire, and even this went off at the third trial. Only one of the shells also failed to explode. Nearly all of them went through the target, and only exploded in the butte. One, however, burst on striking the target, and one exploded within the gun-barrel; but this latter mishap is not necessarily to be attributed to any irregular action of its fuse, for the shells appear to have been badly cast, and one of the walls, oftentimes, by reason of the eccentricity of the central void, is extremely thin.

Six shots were fired in succession in 12 seconds, the cartridges being set in place one by one; then 15 cartridges in 15 seconds, with the use of boxes previously supplied with a certain number of cartridges. The fire might be kept up for some time at the rate of 60 shots per minute—equal to 66 pounds of cast-iron shot off in that space of time. The firing is very regular, and the sighting does not appear to undergo any notable variation.

Each shell breaks up into 12 or 15 fragments, large enough to produce mortal wounds at a certain distance from the point where they explode. Most commonly its bottom-piece (*culot*) separates from the rest without breaking, though lines of cleavage may have been made in it beforehand.

A notable drawback is the rapid fouling of the gun by the shells, which is manifest after the first few shots, and quickly grows worse. Doubtless this is attributable to the bad quality of the latten forming the jacket of the projectile.

We should say that the mechanism of Hotchkiss's revolving cannon works with certainty and regularity, and that its ammunition would do good service, were the shell better fastened in the cartridge. This shell is an article of difficult and delicate manufacture, and of a rather high price. The cannon would doubtless produce formidable effects at ranges approaching those of field-artillery, and the explosive properties of its projectiles give it a great advantage over all other mitrailleuses, since the aim can be regulated by observing the points where the shells fall.

Fertilization of Flowers.—Mr. Meehan last year exhibited, at the Philadelphia Academy of Natural Sciences, a pear having fibrous instead of granular flesh, and a tough rind like that of the apple. He accounted for these phenomena by the theory that apple-pollen had impregnated a pear-pistil. At the meeting of the Academy held January 21st he exhibited an ear of Indian-corn which serves to confirm his hypothesis. As soon as the "silk," that is, the pistils, appeared, the pollen in the "tassel" of a quite different variety of corn was set in a bottle near it, the plant's own tassel having been cut away some time previously. Soon this tassel was taken away, and replaced by another of a different species. The result was that *each grain* bore a resemblance to the grain of the two impregnating plants, the base having the color of the one, and the upper half the color of the other. Thus it is seen that one ovule may receive an impress from the pollen-grains of at least two separate plants, even though a considerable time intervene between the first and second impregnation.

Madeira as a Health-Resort.—That invalids, who visit distant climes in pursuit of conditions more favorable to health than they can find at home, are but too often led by false hopes, is an every-day observation. A writer in the London *Times*, who went out to Madeira last year for the benefit of his health, has proved the truth of this observation by his own experience, and labors to convince other invalids that they can find, nearer home, advantages every way superior to those enjoyed at Madeira. The temperature of that island is no doubt remarkably equable, the thermometer very rarely indicating under 60° or over 78°; but yet from the latter end of February up to the date of the writer's letter, the beginning of May, the weather was as unpleasant as could prevail even in England. During March there were keen, piercing winds, and occasional hot sun, and April was a succession of chilly, damp, and rainy days. Thus the patient is almost sure to lose, in the discomforts of spring, all the strength he may have gained during the summer and winter.

A Portuguese never condescends to let apartments, and the invalid must put up with the very imperfect accommodation of the hotels, where comfort and sanitation are entirely disregarded. The writer regards the Madeira climate as especially unfavorable to youthful invalids. Finally, it would appear that every obstacle is placed in the way of those who wish to return home from the island. The writer's conclusion is, that the chances of recovery for a consumptive are far better at home, surrounded by the conveniences and comforts of life, than in Madeira, where the only favorable condition is the climate, and where even that advantage is more than balanced by the storms of the spring season.

Lacustrine Dwellings in Germany.—The remains of ancient habitations raised on piles are of rare occurrence in Germany, and hence the discovery last year of the *débris* of such structures in the bed of the river Elster, near Leipsic, awakened a lively interest. The discovery was made by Herr Jentzsch, of the Geological Institute of Austria. The order of the visible strata at this point is as follows: At the base is found a layer of sandstone; on this a lacustrine clay. Both of these belong to the upper portions of the quaternary rock. In the clay are two beds containing the remains of plants, and among these are found leaves of the willow and oak, fruit of the *Acer*, and sundry other vegetal fragments. Above these occurs a layer of roots some inches in depth, which shows that the surface of the soil remained at this level for a considerable period. The uppermost layer, two to three metres thick, was produced by an inundation. The piles discovered by Jentzsch in the bed of the Elster are set in the clay and covered over with this silt. They are arranged in circles, with their lower ends pointed, and their upper extremities connected by horizontal ties of oak.

Among the animal remains found here are, the lower jaw of an ox, with its teeth, stags' heads, the long bones of some mammal yet undetermined, and shells of the *unio* and *anodon*. No traces of human remains have been found, though fragments of pottery and charcoal are met with; also two stone hatchets.

Industrial Occupations of Women.—The following notes of avocations followed by women in the United States, taken from the last census returns, give a curious exhibit of the extent to which woman is now invading provinces of industry which once were supposed to belong exclusively to the other sex: Agricultural laborers, 373,332; stock-herders and stock-raisers, 75; architect, 1; auctioneers, 12; barbers and hairdressers, 1,179; clergy, 67; dentists, 24; hostlers, 2; hunters and trappers, 2; lawyers, 5; livery-stable keepers, 11; midwives, 1,186; physicians and surgeons, 525; scavengers, 2; sculptors, 4; teachers, 84,047; whitewashers, 391; bankers and brokers, 15; barkeepers, 70; boat-hands, 30; canal-boat hands, 10; dray-drivers, teamsters, etc., 196; newspaper-carriers, 7; pilot, 1; undertakers, 20; bell-foundery operatives, 4; brass-founders, 102; brewers, 8; brick-makers, 74; carriage-trimmers, 32; charcoal and lime burners, 5; cigar-makers, 1,844; clock-makers, 75; curriers and tanners, 60; distillers, 6; engravers, 29; fishers, 35; gas-works employées, 4; gun and locksmiths, 33; printers, 1,495; shingle and lath makers, 84; tinners, 17; wood-turners and carvers, 44.

Effects of Freezing on Wine and Spirits.—Some experiments on the freezing of wines and spirits are recorded as follows by M. Melsens in the *Comptes Rendus* of the French Academy of Sciences. Brandy cooled to as low as *minus* 35° C. was pronounced exquisite, and some connoisseurs pronounced it all the mellower in proportion as the temperature was reduced. About — 30° C., alcoholic liquors, containing 50 per cent. of absolute alcohol, become viscid, syrupy, and sometimes opaline. The author solidified spirits (cognac, rum) at — 40° and — 50° C., and says that if they be then taken as ices, or sherbet, with a spoon, it is surprising what little sense of cold there is. A spoonful of this ice when placed on the tongue appears to be less cold than ordinary ices, and many persons who have tasted such frozen cognac or rum could scarcely bring themselves to believe that they had on their tongues ices which might be served on dishes of frozen mercury. In fact these ices must be reduced to — 60° C. before the one who tastes them pronounces them "cold;" and scarcely ever will any one pronounce them "very cold." The lowest temperature at which M. Melsens experimented with these frozen alcoholic liquors was — 71° C. If a considerable quantity at that temperature be taken into the mouth, the effect is like that of a spoonful of soup a little too hot. In this case a wooden spoon must be employed, one of metal producing a blister. Placed upon the dry forearm this solid *eau de vie* produces a slight cauterization, without burning, as would a fragment of solid ether or carbonic acid.

The author's experiments on wines were undertaken with a view to discover the means of preserving them. On placing them in a vessel surrounded with a freezing mixture, they were reduced to the condition of a mass of ice-crystals permeated with a colored fluid. This he transferred to a wire sieve, and, by agitating it there, expelled the liquid. The ice on being melted was found to be tasteless, with the merest traces of alcohol. Thus the percentage of alcohol in the wine when deprived of its water is increased, and its keeping quality greatly improved. The author suggests freezing as a method of improving the body of light wines, which otherwise will not bear transportation, and says that if in France wine-growers will adopt the plan of heating their wines in order to check the "diseases" to which they are subject, and of freezing them, so that they may keep, the trade in wine will be rendered far less fluctuating than it now is. It will be possible to keep on hand a large quantity of wine, so as to offset the effects of bad harvests.

What Darwinism means.—From our esteemed contemporary, the *Lens*, of Chicago, we take the following correction of current misapprehensions as to the true meaning of Darwinism: "Prof. Edward S. Morse," says the *Lens*, "delivered, early in March, two lectures in Chicago, the one with the title 'From Monad to Man,' the other on 'Evolution.' In the lecture on 'Evolution' Prof. Morse makes two statements worthy of special note. In the one he alleges that the prejudice against Darwin, and the ridicule so freely expended upon him, are based on an entire misapprehension. Darwin has never taught that man is a development from a monkey, or from any lower species. Nor is there any thing in his philosophy that even admits of inference to this effect. He simply teaches, or suggests the probability, that man or monkey is simply 'evolved' from a lower basis of life. The several streams, all starting from one source, as they branch—the one goes to the monkey, and there stops; and the other to man, and there stops. It is not Darwinism that man himself, or the monkey itself, shall keep on till there is development into something higher and different. The other statement was to the effect that science deals with phenomena, not with the intelligent cause.

It notes and defines law; has nothing to do with the creator of the laws. Science, therefore, cannot take the place of religion. And when the man of science passes from the law to the author of law, he drops the character of scientist and assumes to teach religion. The scientist is not, therefore, censurable for restricting himself exclusively to the phenomena, making no reference to the power lying behind phenomena."

A Hoarding Bird.—A writer in *Hardwicke* has discovered in the nuthatch, or nutpecker, the habit of laying up in its harvest-season a store of nuts for a winter provision, a characteristic which has been hitherto observed, as the writer remarks, in no other birds save tame individuals of the family *Corvidæ*. One day last September a nuthatch was seen to light upon a potato-hill, and there to drop something, which it drove into the earth with repeated taps of its beak. On investigation a nut was discovered there, and soon after six other nuts were found buried in close proximity to it. Again, so late as November 1st, the same bird was seen to bury a nut in a flower-bed, and, in the depth of winter, if watched, he will be found to visit frequently his hoards, taking with him, from time to time, so much as he needs for his present wants.

Artificial Respiration in Snake-Poisoning.—The publication of Dr. Fayrer's work on the *Thanatophidia* of India has led to a very active investigation of the subject of snake-poisoning. The author himself has made several experiments on the efficacy of artificial respiration as a means of counteracting the venom. In one of these he kept the heart beating for nine hours after the development of fatal symptoms. The heart then failed only from imperfect respiration carried on in the cold. If there is an analogy, as Dr. Fayrer supposes, between snake-venom and curare, there is every reason to expect that the remedy (respiration) which is effectual in antagonizing the latter will be equally effectual against the former.

Dr. Richards, of Balasore, thus details an experiment, made by himself, where the heart's action was kept up for 24 hours and 35 minutes: "This is, perhaps, the most remarkable case of its kind on record. The dog was, to all appearances, dead when the artificial respiration was commenced. Two hours and a half later convulsive movements were excited by the application of the galvanic current, but at seven o'clock there was no response, and the body of the dog was cold. At this time the eyes presented a glazed appearance, being perfectly dry. The pupils were dilated, and the heart was beating feebly. Had artificial respiration been now stopped the heart would have ceased to beat almost at once."

At noon the next day the dog appeared as if it would recover. "The eyes had lost the glazed appearance, lachrymation was restored, and there were winking of the lids on dropping water into the eye, attempts at deglutition when water was put into the mouth, and the heart was beating vigorously."

As artificial respiration must be kept up for hours, or even for days, Dr. Fayrer recommends the use of a special apparatus for this purpose, to be worked by steam.

NOTES.

One of the chief attractions of this year's International Exhibition in London is Mr. Buckmaster's School of Cookery, where lectures are given twice a day on culinary processes, fully illustrated by practical experiments. It is found impossible, with the present arrangements, to accommodate all who apply for admission to the lectures. Special attention is given to the best modes of preparing canned meat, a valuable food-stuff, against which Britons have very strong prejudices. There is certainly room for improvement in the popular culinary processes in vogue the world over, but nowhere perhaps is this improvement more needed than in English-speaking countries. We waste an enormous amount of good provisions.

The sound of the salutes fired by the British iron-clad fleet at Spithead on Monday, June 23d, in honor of the Shah's visit, was heard at Tedstone, Worcestershire, distant from Spithead 100 miles. A correspondent of the *Times*, writing from Tedstone on the 23d, says: "We have all heard a long continuous series of sounds, shaking the windows on the south side of the house, and resembling exactly the effect of a distant salute. My gardener states that he heard similar sounds between 11 and 12. My house is on a hill, from 400 to

500 feet above sea-level. On referring to the *Times* of Saturday, with to-day's programme, I find that the time (2.15) may coincide with one of the general salutes at Spithead, though at this distance it seems almost impossible that the vibration should be felt. We are familiar with the sound of salutes, from frequent summer visits to Stoke's Bay. I send the facts for what they may turn out to be worth."

In connection with the shortest railway route to India, *via* the Persian Gulf, an Englishman, resident in Damascus, suggests as worthy of consideration the ancient Roman causeway, which, it is said, exists, in an almost perfect state, from Bozrah in the Hauran, to Bassorah on the Persian Gulf. The roadstead of Acre might easily be formed into a good port, to serve as the Mediterranean terminus of the road.

Prof. Ferrier has obtained a grant from the Royal Society of London, which will enable him to pursue his studies on monkeys. He has already made some progress in these researches, as may be seen from the following passage taken from a letter written by Dr. Lauder-Brunton to the editor of the *Philadelphia Medical Times*. "Already his experiments on his Simian cousins have commenced," writes Dr. Brunton, "and the results are most satisfactory. He can make an animal follow his command by simply touching different parts of the brain, by the electrode, and 'eyes right,' 'eyes left,' 'eyes open,' 'eyes shut,' 'mouth open,' 'mouth shut,' 'tongue out,' 'tongue in,' etc., follow as certainly as the machinery of a London penny steamer follows the commands, 'ease her,' 'stop her,' 'back her.'" Whereupon the *Medical Times* observes that "it certainly looks squally for Prof. Brown-Séquard's theory of the origin of brain-symptoms."

According to the *Scientific American*, a Canadian inventor has originated a method of producing from the milk-weed, or other plants of the genus *Asclepias*, as also from flax and other seeds, a gum designed to serve as a substitute for India-rubber. The substances are macerated and fermented, and the liquid is then reduced, by evaporation, to a thick, gummy mass, possessed of many of the valuable qualities of rubber.

An "Acclimatization Society," for the introduction of singing-birds, as also of birds serviceable to the gardener and farmer, has been founded in Cincinnati. During the past spring the expenditure of the society amounted to $5,000, and fifteen European species of birds were introduced. The skylark is already acclimated at Cincinnati, and in the country around the summer air is vocal with his cheerful song.

From a microscopical examination of the blood of 143 lunatics, by Dr. H. Sutherland, of London, it appears that the blood in the insane generally contains an excess of the white corpuscles, and that its red corpuscles frequently show no tendency to arrange themselves in rouleaux. The coexistence of these two abnormal characters in the blood indicates, according to Dr. Sutherland, a very low degree of vitality. In ten men, suffering from general paralysis, whose blood was found to exhibit one or other or both of these conditions, five died within three months after their blood was examined.

Notwithstanding that during the past few years great efforts have been made both here and in England to put a stop to commercial frauds and adulterations, the evil still continues almost undiminished. For instance, it is estimated that the milk vended in English towns is impoverished to the extent of at least 25 per cent. on the average; in some cases the impoverishment amounts to as much as 50 per cent. But the most glaring fraud of this kind on record was recently perpetrated in Ireland. Two milk-dealers were arrested in Dublin and convicted of selling milk containing, in the one case, 60, and in the other 75 per cent. of water.

Herr Eimer has recently found on a precipitous rock near the island of Capri a new species of lizard. It is blue all over, with dark spots on the back, while all the lizards in Capri are of a bright green, with only a little blue at the extremities. The rock is destitute of vegetation, and of a blue color. When at rest the lizard is hardly visible, its color being so like that of the rock. The rock, which is frequented by birds of prey, was at one time connected with Capri, and the blue lizards are supposed by Herr Eimer to be descended from the green, but transformed by natural selection to blue.

"A Constant Reader" wishes to know how to pronounce the name of the author of "Physics and Politics," Mr. Walter Bagehot. We gave the pronunciation of the name in a notice of the book in the February number. It is not Bag-hot, or Bag-shot, but Baj-ote, the *a* being sounded as in *badge*.

M. Merget, of the Paris Academy of Sciences, has solved the problem of producing indelible photographic proofs. He employs for this purpose salts of platinum, palladium, and iridium, reducing them with vapors of mercury, iodine, and hydrogen. The proof so obtained is absolutely unalterable, no matter how long it may be kept, as it contains no substance which can be affected by light.

THE

POPULAR SCIENCE MONTHLY.

OCTOBER, 1873.

SILK-WORMS AND SERICULTURE.[1]

By A. DE QUATREFAGES.

TRANSLATED BY ELIZA A. YOUMANS.

GENTLEMEN: When your honorable director invited me to speak before you, I felt much embarrassed. I desired both to interest and instruct you, but the subjects with which I am occupied are of too abstract a nature to offer you much interest. In entering upon them I run the risk of tiring you, and, as people who are tired are little instructed, my aim would be doubly missed.

However, among the animals I have studied, there is one which, I think, will awaken your attention. I mean the silk-worm. Its history is full of serious instruction. It teaches us not to despise a being because, at first, it seems useless; it proves that creatures, in appearance the most humble, may play a part of great importance to the world; it shows us that the most useful things are often slow to attract public attention, but that sooner or later their day of justice arrives. It teaches us, consequently, not to despair when valuable ideas or practical inventions are not at first welcomed as they should be, for, though their triumph is delayed, it is not less sure.

Perhaps, also, in choosing this subject, I have yielded a little to national egotism. I was born in that province which was the first in France to understand the importance of the silk-worm; which owes to this industry, fertilized by study and management, a prosperity rarely equalled, and which, of late cruelly smitten, bears its misfortunes with a firmness worthy of imitation.

We are to speak, then, of industry, of studious care, of perseverance, of courage; I am certain that you will be interested.

Pemit me, at first, to make a supposition—what we call an hypothesis: what would you say if a traveller, coming from some distant

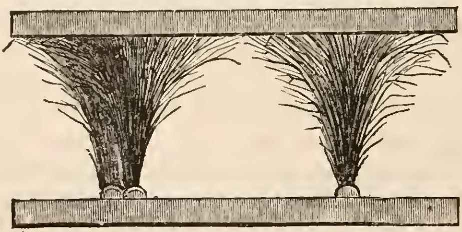
[1] A lecture delivered at the Imperial Asylum at Vincennes.

country, or a philosopher, who had found in some old book forgotten faets, should tell you, "There exists, in a eountry three or four thousand leagues from here, in the south of Asia, a tree and a eaterpillar. The tree produees nothing but leaves whieh nourish the eaterpillar." To a eertainty, most of you would say at first, "What of it?"

If the traveller or the man of learning should go on to say: "But this caterpillar is good for something; it produees a speeies of coeoon, whieh the inhabitants know how to spin, and whieh they weave into beautiful and durable fabries. Would you not like to enter upon the manufacture?" You would infallibly reply: "Have we not wool from whieh to weave our winter vestments, and hemp, flax, and eotton, for our summer elothing? Why should we cultivate this eaterpillar and its eocoons?"

But suppose that the traveller or philosopher, insisting, should add: "We should have to aeelimate this tree and this eaterpillar. The tree, it is true, bears no fruit, and we must plant thousands of them, for their leaves are to nourish the caterpillar, and it is neeessary to raise these eaterpillars by the millions. To this end we must build houses expressly for them, enlist and pay men to take care of them—to feed them, watch them, and gather by hand the leaves on which they live. The rooms where these inseets are kept must be warmed and ventilated with the greatest eare. Well-paid laborers will prepare and serve their repasts, at regular hours. When the moment arrives for the animal to spin his cocoon, he must have a sort of bower of heather (Fig. 1), or branehes of some other kind, properly prepared.

Fig. 1.



Sprigs of Heather arranged so that the Silk-worm may mount into them.

And then, at the last day of its life, we must, with the minutest eare and the greatest pains, assure its reproduction." Would you not shrug your shoulders and say, "Who, then, is sueh a madman as to spend so much care and money to raise—what?—some eaterpillars!"

Finally, if your interloeutor should add—"We will gather the eocoons spun by these eaterpillars, and then the manufaeture which spins them will arise, which will eall out all the resources of mechanics. Still another new industry would employ this thread in fabricating stuffs. The value of this thread, of these tissues, would be counted by hundreds of millions for Franee alone; millions that would benefit agriculture, industry, commerce; the producer and the artisan, the laborer in the fields, and the laborer in towns. Our caterpillar and its products will find a place in the elaborate treatises of statesmen; and a time will come when France will think herself happy that the sovereign of a distant empire, some four thousand leagues away, had been pleased to permit her to buy in his states, and pay very dear for, the eggs of this caterpillar"—you would abruptly turn your back and say, "This man is a fool." And you would not be alone: agriculturists, manufacturers, bankers, and officials, could not find sarcasms enough for this poor dreamer.

And yet it is the dreamer who is in the right. He has not traced a picture of fancy. The caterpillar exists, and I do not exaggerate the importance of this humble insect, which plays a part so superior to what seemed to have fallen to it. It is this of which I wish to give you the history.

Let us first rapidly observe this animal, within and without. We call it a silk-worm, but I have told you it was a caterpillar. (Fig. 7.) I add that it has nothing marked in its appearance. It is larger than the caterpillars that habitually prey upon our fruit-trees, but smaller than the magnificent pearl-blue caterpillar so easy to find in the potato-field. Like all caterpillars, it is is transformed into a butterfly. To know the history of this species is to know the history of all others.

Here in these bottles are some adult silk-worms, but here also are some large pictures, where you will more easily follow the details that I shall point out, beginning with the exterior.

At one of the extremities of its long, almost cylindrical body (Fig. 7), we find the small head, provided with two jaws. These jaws do not move up and down, as in man and most animals that surround us, but laterally. All insects present the same arrangement.

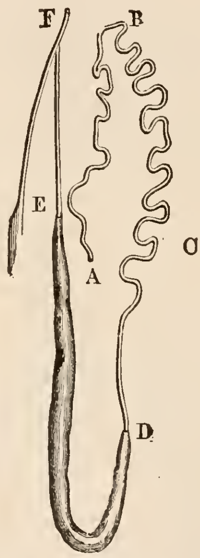
The body is divided into rings, and you see some little black points placed on the side of each of these rings; these are the orifices of respiration. The air enters by these openings, and penetrates the canals that we shall presently find.

The silk-worm has ten pairs of feet. The three first pairs are called the *true feet*, or *scaly feet*; the five last, placed behind, are the *false feet*, or the *membranous feet*. These are destined to disappear at length.

Let us pass to the interior of the body. Here we find, at first, the *digestive tube*, which extends from one extremity to the other. It commences at the *œsophagus*, that which you call the throat. Below you remark an enormous cylindrical sac; it is the *stomach*, which is followed by the very short *intestine*. These canals, slender and tortuous, placed on the side, represent, at the same time, the liver and kidneys. This great yellow cord is the very important organ in which is secreted the silky material (Fig. 2). In proportion as the animal grows, this organ is filled with a liquid which, in passing through the spinners, the orifice of which you see, dries in the air, and forms a thread. This thread constitutes the silk.

The *nervous system* of the animal, placed below the digestive tube, is with insects, as with all animals, of the highest importance. It is the nervous system which seems to animate all the other organs, and particularly the *muscles*. The latter are what we call flesh or meat. They are in reality the organs of movement, with our caterpillar as with man himself. Each of them is formed of elementary fibres that have the property of contracting and relaxing; that is to say, of shortening and lengthening under the influence of the will and of the nervous system. Upon this property depend all the movements executed by any animal whatever.

Fig. 2.



Silk-secreting Apparatus of One Side of a Silk-worm. A, B, C, the part nearest the tail of the worm, where the silk-matter is formed. D, E, enlarged portion—reservoir of silky matter. E, F, capillary tubes proceeding from the two glands, and uniting in one single short canal, F, which opens in the mouth of the worm, at its under lip. Two silk threads are therefore united together, and come out through the orifice with the appearance of a single thread.

I wish you to remark, *à propos* of the caterpillar—of this insect that when crushed seems to be only a formless pulp—that its muscular system is admirably organized. It is superior to that of man himself, at least, in relation to the multiplicity of organs. We count in man 529 muscles; the caterpillar has 1,647, without counting those of the feet and head, which give 1,118 more.

In us, as in most animals, there exists a nourishing liquid *par excellence* that we know under the name of *blood*. This liquid, set in motion by a *heart*, is carried into all parts of the body by *arteries*, and comes back to the heart by *veins*. In making this circuit it finds on its route the lungs filled with air by means of respiration.

In our caterpillar we also find blood and a species of heart, but it has neither arteries nor veins. The blood is diffused throughout the body and bathes the organs in all directions. However, it ought to respire. Here step in the openings of which I have spoken. They lead to a system of ramified canals, of which the last divisions penetrate everywhere, and carry everywhere the air—that fluid essential to the existence of all living beings. In our bodies the air and blood are brought together. In insects the air seeks the blood in all parts of the body.

I have sketched for you a caterpillar when it is full grown. But you well know that living beings are not born in this state. The general law is, small at birth, growth, and death. The caterpillar passes through all these phases.

Fig. 3.

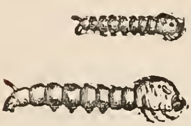
Egg and First Age, lasting five days. (An age is the interval between two moultings.)

Fig. 4.

Second Age, lasting six days.

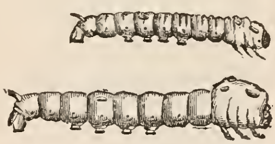
I pass around among you some samples of what we call *seeds of the silk-worm*. These so-called seeds are in reality eggs. The caterpillar comes out of the egg very small; its length at birth is about one-twentieth of an inch. Look at these samples, and you will see how

Fig. 5.



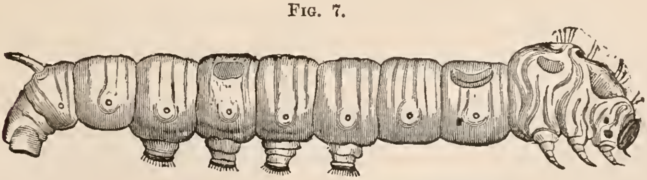
Third Age, lasting six days.

Fig. 6.



Fourth Age, lasting six days.

Fig. 7.



Fifth Age, lasting nine days. The mature worm near the end of its career, and at the time of its greatest voracity.

great is the difference of size between the worm at birth and the full-grown specimens I have shown you. This difference is much greater than in man. A man weighs about forty times as much as the new-born infant; the caterpillar, when perfectly developed, is 72,000 times heavier than when it first came from the egg.

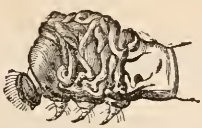
In every thing that relates to the body, there is between men and animals more resemblance than is ordinarily believed. We also come from an egg which essentially resembles all others. That this egg may become a man, it must undergo very great changes, many metamorphoses. But all these changes, all these metamorphoses occur in the bosom of the mother, as they are accomplished within the shell for the chicken. For insects in general, and consequently for the silk-worm, a part of these metamorphoses occur in the open day. Hence they have drawn the attention, excited the curiosity, and provoked for a long time the study of naturalists. Let us say a few words about them.

Scarcely is the caterpillar born than it begins to eat. It has no time to lose in gaining a volume 72,000 times greater than it had at first; so it acquits itself conscientiously of its task, and does nothing but eat, digest, and sleep. At the end of some days this devouring appetite ceases; the little worm becomes almost motionless, hangs itself by the hind-feet, raising and holding a little inclined the anterior of its body.

This repose lasts 24, 36, and even 48 hours, according to the temperature; then the dried-up skin splits open behind the head, and soon along the length of the body. The caterpillar comes out with a new skin, which is formed during this species of sleep.

This singular crisis, during which the animal changes his skin as we change our shirt, is called *moulting*, when it is a question of caterpillars in general. For the silk-worm, we designate it under the name of *sickness*. It is, in fact, for the silk-worm, a grave period, during which it often succumbs, if its health is not perfect.

Fig. 8.



Head of Silk-worm during Moulting; swollen, and skin wrinkled.

Fig. 9.

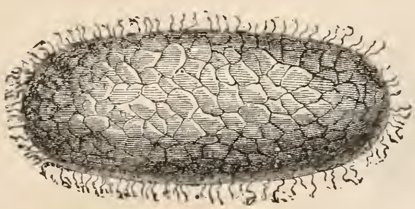
Position of Silk-worm while Moulting.—It remains at rest for from 12 to 24 hours, fasting, but begins to eat an hour after the crisis in which it escapes from the old skin.

The silk-worms change their skin four times. After the fourth moulting comes a redoubled appetite, which permits them to attain their full size in a few days. Then other phenomena appear. The caterpillar ceases to eat, and empties itself entirely; it seems uneasy, wanders here and there, and seeks to climb. Warned by these symptoms, the breeder constructs for it with branches a cradle or bower, into which it mounts. It chooses a convenient place, hangs itself by the hind feet, and soon, through the spinner of which I have spoken (Fig. 2), we see come out a thread of silk. This is at first cast out in any direction, and forms a collection of cords destined to fix the cocoon that is to be spun. Soon the work becomes regular, and the form of the cocoon is outlined. For some hours we can see the worker performing his task across the transparent gauze with which he surrounds himself. By little and little, this gauze thickens, and grows opaque and firm; finally it becomes a cocoon like these I place before you. At the end of about 72 hours the work is done.

Once it has given out its first bit of silk, a worm in good health never stops, and the thread continues without interruption from one end to the other. You see that the cocoon is in reality a ball wound from the outside inward. The thread which forms this ball is 11 miles in length; its thickness is only $\frac{1}{2400}$ of an inch. It is so light that 28 miles of it weigh only $15\frac{1}{3}$ grains. So that $2\frac{1}{5}$ lbs. of silk is more than 2,700 miles long.

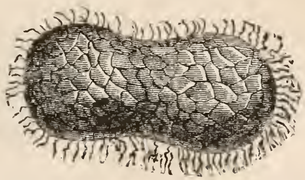
Let me insist a moment on the prodigious activity of the silk-worm while weaving his cocoon. To dispose of its silk when spinning, it moves its head in all directions, and each movement is about one-sixth of an inch. As we know the length of the thread, we can calculate how many movements are made in disposing of the silk in 72 hours. We find in this way that a silk-worm makes nearly 300,000 motions in 24 hours, or 4,166 an hour, or 69 per minute. You see that our insect yields not in activity to any weaver; but we must add that it is beaten by the marvellous machines that the industry of our day has produced.

Fig. 10.



Spherical Cocoon of Bombyx Mori.

Fig. 11.



Cocoon drawn in toward the Middle.

All cocoons are not alike. There exist, in fact, different races of silk-worms, as we have different races of dogs. These differences are less obvious in the animals themselves; they are best seen in the cocoons, which may be either white, yellow, green, or gray; some are round, others oval or depressed in the middle (Figs. 10 and 11). The silk of one is very fine and very strong, that of others is coarse and easily broken. Hence their very different values.

All I have said applies to the silk-worm properly so called—to the silk-worm which feeds on the leaves of the mulberry-tree, the *Bombyx mori* of naturalists. But, some years since, there were introduced into France new species of caterpillars that produce cocoons, and that live upon other leaves than the mulberry. Among these new importations, the two principal ones are the yama-maï worm, which comes from Japan, and feeds upon the leaves of the oak, and the ailanthus worm. The first gives a very beautiful and very fine silk, while that of the second is dull and coarse. But the ailanthus grows very well in unproductive soils, and hence the caterpillar which it nourishes renders an important service.

But let us return to our mulberry caterpillar, or the silk-worm properly so called. We left it at the moment when it disappeared from our eyes enveloped in its cocoon. There, in its mysterious retreat, it becomes torpid once more. It now shortens itself, changes form, and submits to a fifth moulting. But the animal which emerges from the old skin is no longer a caterpillar. It is in some sort a new being; it is what we call a *chrysalis*. This chrysalis scarcely reminds us of the silk-worm. The body is entirely swaddled; we no longer see either head or feet (Fig. 14). The color is changed, and has become a golden yellow. Only by certain obscure movements of the posterior part do we know that it is not a dead body.

This apparent torpor in reality conceals a strange activity in all the organs and all the tissues, which ends in the transformation of the entire being.

In fifteen or seventeen days, according to the temperature, this work is accomplished, and the last crisis arrives. The skin splits on the back; the animal moults for the last time, but the creature that now appears is no longer a caterpillar or a chrysalis: it is a butterfly (Fig. 12).

Fig. 12.

Silk-worm Moth (Male).

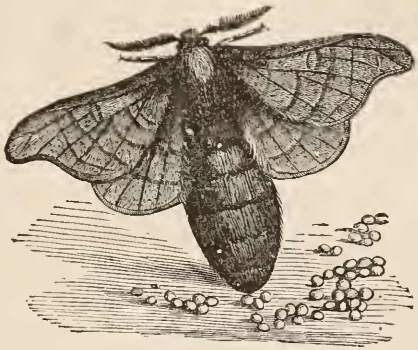
Is it needful to explain the details of this wonderful metamorphosis? The body, before almost all alike, presents now three distinct regions: the *head*, the chest (*thorax*), the belly (*abdomen*). Wings, of which there was not the least vestige, are now developed. In compensation, the hind-feet have disappeared. The fore-feet persist, but you would not know them, they have become so slender, and a fine down covers all the parts.

In the interior, the transformation is also complete. The œsophagus (throat) is no longer a simple reversed funnel; it is a narrow, lengthened tube, with an aërial vessel attached, of which the caterpillar offers no trace. The stomach is strangely shortened. The intestine is elongated, and its different parts, that we found so difficult to distinguish, are very much changed. If we examine in detail all the organs just now indicated, even to the nervous system, we shall find modifications not less striking.

But these are not the strangest changes that have occurred. There are others which still more arrest our attention; they are those which relate to the production of a new generation.

All caterpillars are *neuters*—that is to say, there are no males or females among them. They have no apparatus of reproduction. These organs are developed during the period that follows the formation of the chrysalis while the animal is motionless, and seemingly dead. Marriages occur at the coming out from the cocoon, and, immediately after, the female lays her eggs, averaging about 500 (Fig. 13). This

Fig. 13.



Silk-worm Moth (Female).

done, she dies, the male ordinarily dying first. It is a general law for insects; the butterfly of the silk-worm does not escape it. It is even more rigorous for him than for his brethren that we see flying from flower to flower. From the moment of entering the cocoon, the silk-worm takes no nourishment. When it becomes a butterfly, and has assured the perpetuity of the species, its task is accomplished; there is nothing more but to die.

Such, briefly, is the natural history of the silk-worm. It remains to trace rapidly its industrial history.

Whence came this insect? What is its country and that of the mulberry—for the tree and the animal seem to have always travelled side by side? Every thing seems to indicate that China—Northern China—is its point of departure. Chinese annals establish the existence of industries connected with it from those remote and semi-fabulous times when the emperors of the Celestial Empire had, it is said, the head of a tiger, the body of a dragon, and the horns of cattle. They attribute to the Emperor Fo-Hi, 3,400 years before our era, the merit of employing silk in a musical instrument of his own invention. This date carries us back 5,265 years. They are said to have employed the silk of wild caterpillars, and to have spun a sort of floss. At that time they knew nothing of raising the worm or of winding the cocoon into skeins.

This double industry appears to have arisen 2,650 years before our era, or 4,515 years ago, through the efforts of an empress named Si-ling-Chi. To her is attributed the invention of silk stuffs. You will not be surprised to see that the fabrication of silks should have a woman as its inventor.

Si-ling-Chi, in creating this industry, which was to be so immensely developed, enriched her country. Her countrymen seem to have understood the extent of the benefit, and to have been not ungrateful. They placed her among their deities, under the name of Sein-Thsan, two words that, according to M. Stanislas Julien, signify the first who raised the silk-worm. And still, in our time, the empresses of China, with their maids-of-honor, on an appointed day, offer solemn sacrifices to Sien-Thsan. They lay aside their brilliant dress, renounce their sewing, their embroidery, and their habitual work, and devote themselves to raising the silk-worm. In their sphere they imitate the Emperor of China, who, on his part, descends once a year from his throne to trace a furrow with the plough.

The Chinese are an eminently practical race. No sooner did they understand that silk would be to them a source of wealth, than they strove to obtain a monopoly of it. They established guards along their frontier—true custom-house officers—with orders to prevent the going out of seeds of the mulberry or of the silk-worm. Death was pronounced against him who attempted to transport from the country these precious elements which enriched the empire. So, during more than twenty centuries, we were completely ignorant of the source of these marvellous goods—the brilliant tissues manufactured from silk. For a long time we believed them to be a sort of cotton; some supposed even that they were gathered in the fields, and were the webs of certain gigantic spiders. The price of silk continued so high that the Emperor Aurelian, after his victories in the Orient, refused his wife a silken robe, as being an object of immoderate luxury, even for a Roman empress.

A monopoly founded on a secret ought necessarily to come to an end, particularly when the secret is known by several millions of men. But, to export the industry of Si-ling-Chi, it was needful to risk life in deceiving the custom-house officer. It was a woman who undertook this fine contraband stroke. Toward the year 140 before our era, a princess of the dynasty of Han, affianced to a King of Khokan, learned that the country in which she was destined to live had neither the mulberry nor the silk-worm. To renounce the worship of Sein-Thsan, and doubtless also to do without the beautiful stuffs, so dear to the coquette, appeared to her impossible. So she did not hesitate to use the privileges of her rank to violate the laws of the empire. On approaching the frontier, the princess concealed in her hair some mulberry-seed and eggs of the butterfly. The guards dared not put their hands on the head of a "Princess of Heaven;" eggs and seeds passed the officer without disturbance, and prospered well in Khokan, situated near the middle of Asia.

And so commenced that journey which was not to be arrested till the entire world possessed the mulberry and the silk-worm; but it was accomplished slowly and with long halts. That which had occurred in China occurred everywhere, each new state that obtained the precious seeds attempting prohibition.

The silk-worm and mulberry got to Europe in 552, under Justinian. At this time two monks of the order of St. Basil delivered to this emperor the seeds, said to have come from the heart of Asia. To smuggle them, they had taken still greater precautions than the Chinese princess, for they hollowed out their walking-sticks, and filled the interior with the precious material. The Emperor Justinian did not imitate the Asiatic potentates, but sought to propagate and extend the silk-manufacture. Morea, Sicily, and Italy, were the first European countries that accepted and cultivated the new products.

It was not till the twelfth or thirteenth century that the silk-worm penetrated into France. Louis XI. planted mulberry-trees around his Château of Plessis-les-Tours. Besides, he called a Calabrian named Francis to initiate the neighboring population in raising this precious insect, and developing the several industries that are connected with it. Under Henry IV., sericulture received a great impulse, thanks chiefly, perhaps, to a simple gardener of Nîmes named François Traucat. It is always said that this nurseryman distributed throughout the neighboring country more than four million mulberry-sprouts. In enriching the country, Traucat acquired a considerable fortune; but he lost it foolishly. He had heard of treasures buried near a great castle which commanded the town of Nîmes, and which is called the Castle of Magne. He wished to increase the money he had nobly and usefully gained, by this imaginary gold; he bought the great castle and neighboring ground, and dug the earth, which brought him nothing, till he ruined himself.

The minister of Louis XIV., Colbert, sought also to propagate the mulberry. Sully with reluctance had done the same, and sent trees to various parts of the kingdom, some of which were still living when I was a child. They were called by the name of this minister, and I remember to have seen two of them in my father's grounds, which no longer bore leaves, but were piously preserved as *souvenirs* of their origin.

To lead in the development of sericulture, a man was needed who would not hesitate to set an example, and to make considerable sacrifices. This man, I am proud to say, was a modest officer, Captain

François de Carles, my grandfather. Returning from a campaign in Italy, where he had seen how much the culture of the mulberry en. riched the population, he resolved to transplant this industry into the heart of Cévennes, where were his estates. He proceeded in this way: He made plantations, and, in order to extend them, he did not hesitate to uproot the chestnuts, those old nourishers of the ancient Cévennols.

Fig. 14.

Larva, Pupa, Cocoon, and Moth, of Silk-worm.

To water the mulberries, he constructed ditches and aqueducts; then he forced, so to say, the peasants to take these improved lands at their own price and on their own conditions. In this way he alienated almost all his land, and singularly diminished his fortune; but he enriched the country. The results speak too distinctly to be misunderstood. You shall judge by the figures.

The little valley where Captain Carles made his experiments, and where I was born, belongs to the Commune of Valleraugue. At the time of which I speak, they harvested scarcely 4,400 lbs. of very poor cocoons, that sold for very little. Recently there were produced, before the malady of which I shall presently speak, 440,000 lbs. of excellent quality, valued on an average at $2\frac{1}{3}$ or $2\frac{1}{2}$ francs per pound. At this price, a million of silver money found its way each year into this little commune of not more than 4,000 inhabitants.

Let me remark that this money went not alone to the rich. The small proprietors, the day-laborers, those even who owned not the least land, had the greatest part. In fact, most of the easy proprietors did not raise their own silk-worms; they contracted for them in this way: The laborer received a certain quantity of eggs of the silk-worm on the condition of giving a fifth of the cocoons for an ounce of eggs; they received, besides, enough mulberry-leaves to nourish all the worms from these eggs, *plus* a certain quantity to boot. All the cocoons above this constituted the wages or gain of the raiser.

You see, we had resolved in our mountains this problem, so often encountered and still unsettled, of the association of capital and labor; and resolved it in the best possible way for both. The interest of the proprietor was, in this case, identical with that of the rearer, and reciprocally; for the success of a good workman would equally benefit both parties, and the poor workman could profit only according to his work.

Now, this labor was in reality of little account. Until after the fourth moulting, when the silk-worm is preparing to make his cocoon, the rearing of the worms can be performed by the women and children while the father pursues his ordinary occupation. Only after the fourth moult is he obliged to interrupt his work, and occupy himself, in his turn, in the gathering of leaves. The rearing ended, an industrious family—and such are not rare with us—will have, on an average, from 250 to 500 francs of profit. This bright silver, added to the resources of the year, this profit obtained without the investment of capital, seconded by the wise conduct of our mountaineer Cévennols, leads rapidly to competency. At the end of a few years, the laborer, who had nothing, possesses a little capital to buy some corner of rock, which, by his intelligent industry, he quickly transforms into fertile soil, and in his turn becomes a proprietor.

What I am telling you is not fancy. I speak of facts that have occurred under my own eyes, and that I well know. In the country, and particularly on the soil of our old mountains, people are not strangers to each other, as in our great cities. Between the gentleman and the peasant there are not the same barriers as between the citizen and the laborer in towns. When a child, I played with all my little neighbors; I knew the most secret nooks of the eight or ten houses composing the modest hamlet which bordered the place where

I was born; I saluted by their names the members of all the families of the valley. And now, when I go to the country, it is always a great pleasure to visit these houses, one by one, and take by the hand those from whom I have been so long separated. But this happiness is always mingled with sorrow; the number of those I knew diminishes with each visit, and those who have come since cannot replace them for me.

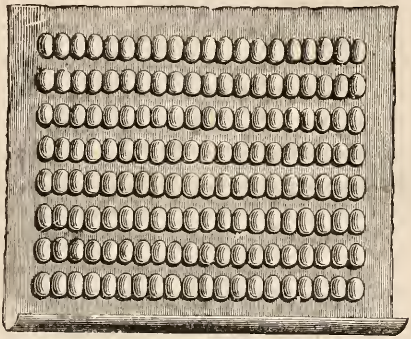
Permit me to give you the history of one of these families. It occurs to me first, as it contrasted with all the others by its miserable dwelling. This was a little thatch-built cottage, standing by itself at the foot of an irregular slope of perfectly bare rocks. It consisted of a single story, with only one room, scarcely larger than one of our bedrooms; the wall, built without mortar, was any thing but regular; the roof consisted of flags of stone, retaining, as well as they were able, a mass of straw and branches. Between the rocks that supported this house and the wall, there was a little place where was kept a pig, the ordinary resource of all Cévennol house-keeping.

This cottage was occupied, when I was eleven or twelve years old, by a man with his wife and four children. The father and mother worked in the field; the eldest child, scarcely of my age, had begun to be useful, particularly in the time of gathering the mulberry-leaves; the smaller ones drove the pig along the road, where it grew and fattened, the best it could, without any expense.

After an absence of ten years, I returned to my mountains, and the first thing was to call upon my old neighbors, those of whom I have spoken among the rest. In approaching, I scarcely knew the place. The rocks that supported the house had disappeared to make way for those *traversiers* of which I shall tell you presently; the house had been rebuilt, it had gained a story, and was of double its former extent; its walls were laid in mortar; its roof covered with beautiful slate. The master of the house was absent, but his wife welcomed me with a glass of wine from a neat walnut table. Then she showed me, with proper pride, a room with two beds at the farther end, the first portion being devoted to the rearing of silk-worms; and, above all, the favorite article of furniture of all good Cévennol housekeeping—an immense cupboard of walnut, crammed with clothing, dresses, and raiment of all sorts. At the same time she gave me news of all the family: the eldest son was a soldier; a daughter was married; the eldest remaining children attended to the business, and, as of old, the younger ones ran about watching the pig. I clasped with pleasure the hand of this brave woman, because this competence was the fruit of good conduct, of industry, of perseverance, and of economy. And what the silk-worm did in ten years for one family it has been doing for nearly a century for the whole region of Cévennes, because among them you generally find the same elements of success.

That you may better understand me, I wish to give you some idea of these valleys. Let me sketch for you the one I know best, the one in which I was born. It is composed of ascents so steep that, when two neighboring houses are placed one above the other, the cellar of the upper one is on the same level as the garret of the lower one. There is not much earth on these declivities, and the rocks stick out everywhere. But it is, as it were, from the rocks themselves that our mountaineers make their mulberry-plantations. They proceed in this way: They first break up the rocks, and with the larger

Fig. 15.



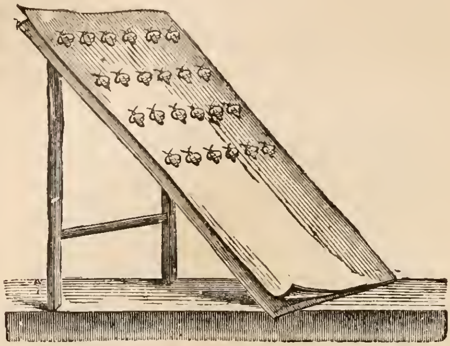
Sheets of Paper, with Rows of Cocoons prepared for the Exit of the Moths designed for laying Eggs.

stones so obtained they raise a wall; then, with the smaller pieces, they fill up the interval between the wall and the mountain. This done, they bring upon their backs, from the bottom of the valley, soil and manure enough entirely to fill the space. This is what is called a *traversier*, and it is in this soil that most of the mulberry-trees are planted. I have seen a bridge built across a mountain-stream expressly to give foothold for two or three of these precious trees. To pay for all this preparation the produce should be very great. The following figures give the average value of ground planted to mulberries for 20 years:

Traversiers not watered . . .	1 acre,	9,800 francs.
Fields watered	1 acre,	12,000 "
Meadows planted with mulberries .	1 acre,	12,400 "

and even then the money yielded five per cent. This price, which some would not believe when I told them, has been officially confirmed by M. de Lavergne, in his remarkable writings upon French agriculture. This value of land, and the way it has been obtained, explain the nature of our country's wealth. With the exception of some families recently enriched by the silk-manufacture and the silk-trade, the level of this wealth, although very high, is more of the nature of general competence than of great fortunes. Industry and economy have produced general well-being, without the growth of offensive differences. I cannot say how it is now, but in my childhood there were no paupers in our commune, except two infirm people who were supported in their misfortunes by voluntary aid.

Fig. 16.



Sheets of Paper stuck into Screens, and inclined for the Reception of Moths.

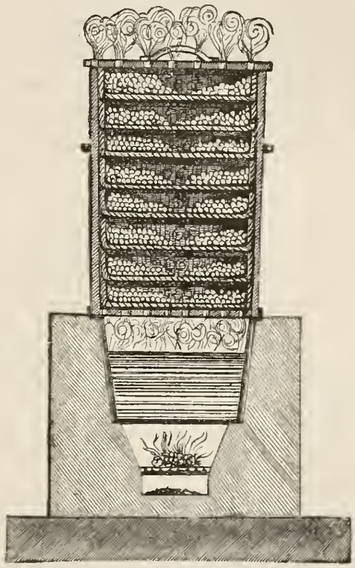
These striking results could not fail to affect the neighboring country. This example of the culture of the mulberry was imitated throughout the south of France, and adopted more or less in other departments. You can judge of the progress made in this culture by the following figures, giving the quantity of cocoons produced annually:

From 1821 to 1830	22,000,000 pounds.
" 1831 " 1840	31,000,000 "
" 1841 " 1845	37,000,000 "
" 1846 " 1852	46,000,000 "
" 1853	56,000,000 "

These 56,000,000 lbs. of cocoons sold at from 2⅓ to 2½ francs per lb., representing a value of about 130,000,000 francs. Now, these millions all went to agriculture, to the first producer; and so they added to the national wealth at its most vital source. If this progress had continued, in a few years we should have been able to supply our own manufactures, and relieve ourselves of the tribute of 60 or 65,000,000 francs that we pay to foreign countries. But, unhappily, at the moment when this culture was most prosperous, when mulberry-plantations were springing up on all sides, fed by the nurseries which were each day more numerous, all this prosperity disappeared before the terrible scourge to which I alluded in the beginning of my discourse.

Like all our domestic animals, the silk-worm is subject to various maladies. One, called the *muscardine*, that for a long time was the terror of breeders, is caused by a species of mould or microscopic mushroom. This mushroom invades the interior of the body of the insect. After affecting all the tissues, this vegetal parasite sometimes suddenly appears upon the outside of the body in the form of a white powder. Each grain of this powder, falling upon a silk-worm, plants the seed of this formidable mushroom, the ravages of which will destroy all the worms of a rearing-chamber in a few hours. Happily, science has found the means of killing these seeds, and of completely disinfecting the locality. At the very moment when this victory was announced, another yet more terrible scourge, the *pébrine*, appeared. The muscardine caused isolated disaster; it had never been so widespread as seriously to injure the general business. Not so this other

FIG. 17.



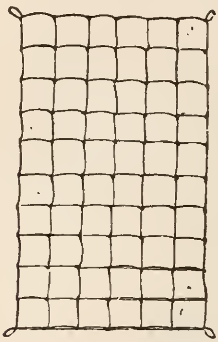
APPARATUS FOR STIFLING THE CHRYSALIS IN THE COCOONS.

malady. It is a true epidemic, which attacks life at its very source in an inexplicable fashion. It is a pestilence like the cholera. Under the influence of this scourge, the chambers of the silk-worm no longer thrive; most of the worms die without producing silk. Those that survive as butterflies give infected eggs, and the next generation is worse than the first. To get healthy eggs, we had to go to the neighboring countries; but other countries have been invaded in their turn. To-day we have to get them in Japan. Even when the egg is healthy, the epidemic bears equally on its product; a great part of the worms always succumb, and when the breeder gets half a crop he is very happy. Upon the whole, the great majority of breeders have worked at a loss since the invasion of this disease.

You understand the consequences of such a state of things, continued since 1849. The people make nothing; they lose, and yet they have to live and cultivate their ground. In this business the profits melt away rapidly, and particularly where the mulberry was the only crop, as at Cévennes, misery has taken the place of comfort. Those who once called themselves rich are to-day scarcely able to get food to eat. Those who used to hire day-laborers to gather their harvest have become day-laborers, and the laborers of former times have emigrated. This will give you an idea of the extremities to which they are reduced, for to uproot a mountaineer of Cévennes he must be dying of hunger.

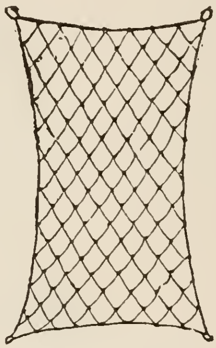
To escape a fatality so heavy, these people have displayed perseverance and courage of the highest kind. They have undertaken distant journeys to get non-infected eggs. More than one has not come back from these journeys, where it was needful to struggle against great fatigue in inhospitable countries. Although they fell not on a field of battle, struck by ball or bullet, they were true soldiers; and, although they did not carry arms, they died in the service of the country.

Fig. 18.



Square Net.

Fig. 19.



Lozenge-shaped Net.

Nets used to separate the worms from their faded and withered leaves. Fresh leaves are spread on these nets, and the worms leave the old food to get on to the new leaves.

During seventeen years this exhaustion has been most aggravated in places chiefly devoted to sericulture. But, if these local sufferings merit all our sympathy, their general consequences still more demand our attention. Confidence in the culture of the silk-worm has diminished wherever it was not the exclusive occupation. Where other crops could replace it, that of the mulberry was easily discouraged. In many countries they have destroyed the tree so lately known as the tree of gold.

As the foregoing interesting discourse was delivered in 1866, the following statement of Prof. Huxley regarding the *pébrine* malady, made in 1870, in his address before the British Association, will be interesting.—[Editor.

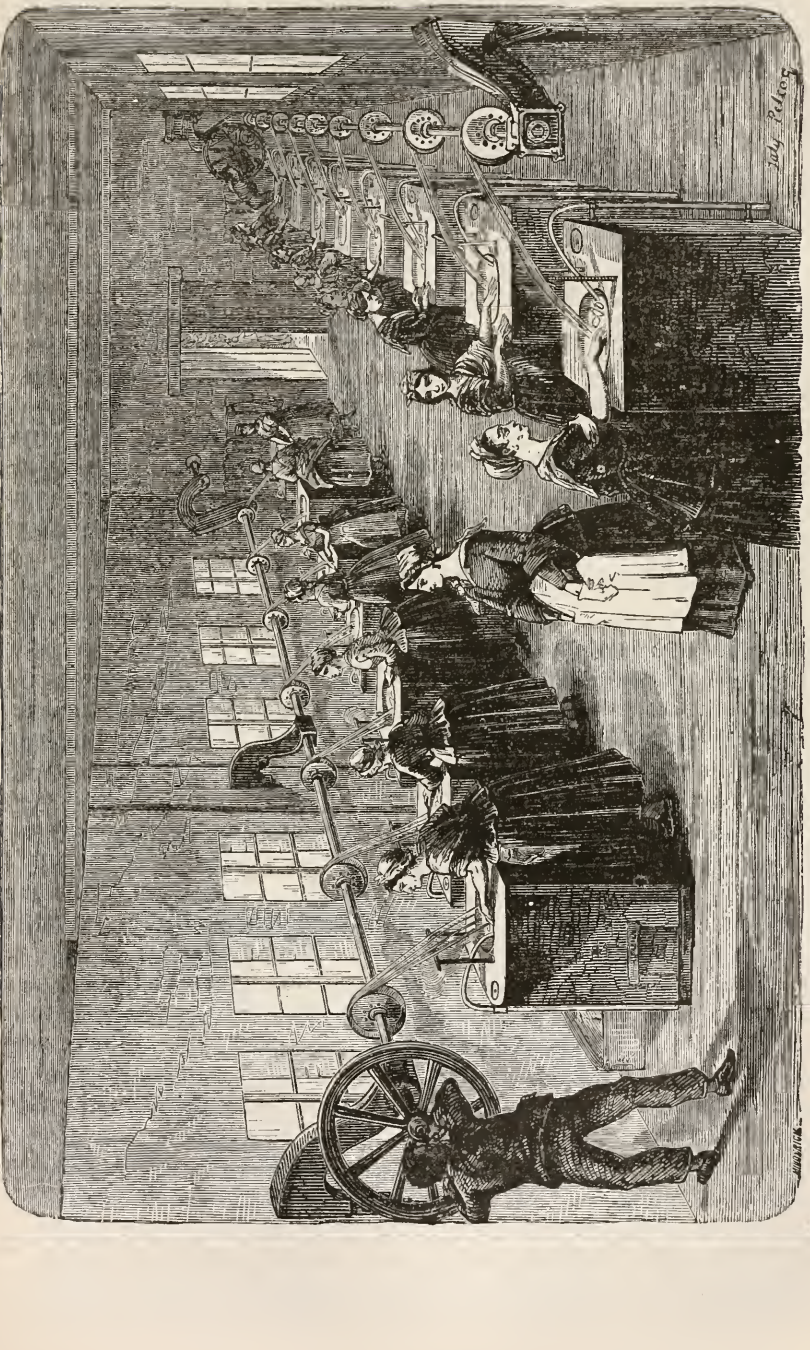


Fig. 20.—Silk-winding Establishment.—Each woman has a copper containing water that she heats by steam, and plunges the cocoons into this hot water to soften the gummy matter that sticks the threads together. She then beats them with a light birch broom to catch hold of the filaments, which she seizes with her fingers and joins into threads, which are drawn out on revolving wheels.

"The Italian naturalist, Filippi, discovered, in the blood of silk-worms affected by this strange disease, *pébrine*, a multitude of cylindrical corpuscles, each of about $\frac{1}{6000}$ of an inch long. These have been carefully studied by Lebert, and named by him *Panhistophyton;* for the reason that, in subjects in which the disease is strongly developed, the corpuscles swarm in every tissue and organ of the body, and even pass into the undeveloped eggs of the female moth. The French Government, alarmed by the continued ravages of the malady and the inefficiency of the remedies which had been suggested, dispatched M. Pasteur to study it, and the question has received its final settlement. It is now certain that this devastating, cholera-like *pébrine* is the effect of the growth and multiplication of the *Panhistophyton* in the silk-worm. It is contagious and infectious, because the corpuscles of the *Panhistophyton* pass away from the bodies of the diseased caterpillars, directly or indirectly, to the alimentary canal of healthy silk-worms in their neighborhood; it is hereditary, because the corpuscles enter into the egg. There is not a single one of all the apparently capricious and unaccountable phenomena presented by the *pébrine*, but has received its explanation from the fact that the disease is the result of the presence of the microscopic organism *Panhistophyton.* M. Pasteur has devised a method of extirpating the disease, which has proved to be completely successful when properly carried out."

MENTAL SCIENCE AND SOCIOLOGY.

By HERBERT SPENCER.

PROBABLY astonishment would make the reporters drop their pencils, were any member of Parliament to enunciate a psychological principle as justifying his opposition to a proposed measure. That some law of association of ideas, or some trait in emotional development, should be deliberately set forth as a sufficient ground for saying "ay" or "no" to a motion for second reading, would doubtless be too much for the gravity of legislators. And along with laughter from many there would come from a few cries of "question:" the entire irrelevancy to the matter in hand being conspicuous. It is true that during debates the possible behavior of citizens under the suggested arrangements is described. Evasions of this or that provision, difficulties in carrying it out, probabilities of resistance, connivance, corruption, etc., are urged; and these tacitly assert that the mind of man has certain characters, and under the conditions named is likely to act in certain ways. In other words, there is an implied recognition of the truth that the effects of a law will depend on the manner in which human intelligence and human feeling are influenced by it. Experiences of men's conduct which the legislator has gathered, and which lie partially sorted in his memory, furnish him with empirical notions that guide his judgment on each question raised; and he would think it folly to ignore all this unsystematized knowledge about people's characters and actions. But, at the same time, he regards as foolish the proposal to proceed, not on vaguely-generalized facts, but on facts accurately generalized; and, as still more foolish, the proposal to merge these minor definite generalizations in generalizations expressing the ultimate laws of Mind. Guidance by intuition seems to him much more rational.

Of course, I do not mean to say that his intuition is of small value. How should I say this, remembering the immense accumulation of experiences by which his thoughts have been moulded into harmony with things? We all know that when the successful man of business is urged by wife and daughters to get into Parliament, that they may attain a higher social standing, he always replies that his occupations through life have left him no leisure to prepare himself, by collecting and digesting the voluminous evidence respecting the effects of institutions and policies, and that he fears he might do mischief. If the heir to some large estate, or scion of a noble house powerful in the locality, receives a deputation asking him to stand for the county, we constantly read that he pleads inadequate knowledge as a reason for declining: perhaps hinting that, after ten years spent in the needful studies, he may have courage to undertake the heavy responsibilities proposed to him. So, too, we have the familiar fact that, when, at length, men who have gathered vast stores of political information gain the confidence of voters who know how carefully they have thus fitted themselves, it still perpetually happens that after election they find they have entered on their work prematurely. It is true that beforehand they had sought anxiously through the records of the past, that they might avoid legislative errors of multitudinous kinds, like those committed in early times. Nevertheless, when acts are proposed referring to matters dealt with in past generations by acts long since cancelled or obsolete, immense inquiries open before them. Even limiting themselves to the 1,126 acts repealed in 1823–'29, and the further 770 repealed in 1861, they find that to learn what these aimed at, how they worked, why they failed, and whence arose the mischiefs they wrought, is an arduous task, which yet they feel bound to undertake lest they should reinflict these mischiefs; and hence the reason why so many break down under the effort, and retire with health destroyed. Nay, more—on those with constitutions vigorous enough to carry them through such inquiries, there continually presses the duty of making yet further inquiries. Besides tracing the results of abandoned laws in other societies, there is at home, year by year, more futile law-making to be investigated and lessons to be drawn from it; as, for example, from the 134 public acts passed in 1856–'57, of which all but 68 are wholly or partially repealed. And thus it happens that, as every autumn shows us, even the strongest men, finding their lives during the recess overtaxed with the needful study, are obliged so to locate themselves that by an occasional day's hard riding after the hounds, or a long walk over the moors with gun in hand, they may be enabled to bear the excessive strain on their nervous systems. Of course, therefore, I am not so unreasonable as to deny that judgments, even empirical, which are guided by such carefully-amassed experiences, must be of much worth.

But, fully recognizing the vast amount of information which the legislator has laboriously gathered from the accounts of institutions and laws, past and present, here and elsewhere, and admitting that, before thus instructing himself, he would no more think of enforcing a new law than would a medical student think of plunging an operating-knife into the human body before learning where the arteries ran, the remarkable anomaly here demanding our attention is, that he objects to any thing like analysis of these phenomena he has so diligently collected, and has no faith in conclusions drawn from the *ensemble* of them. Not discriminating very correctly between the word "general" and the word "abstract," and regarding as *abstract* principles what are in nearly all cases *general* principles, he speaks contemptuously of these as belonging to the region of theory, and as not concerning the law-maker. Any wide truth that is insisted upon as being implied in many narrow truths, seems to him remote from reality and unimportant for guidance. The results of recent experiments in legislation he thinks worth attending to; and, if any one reminds him of the experiments he has read so much about, that were made in other times and other places, he regards these also, separately taken, as deserving of consideration. But, if, instead of studying special classes of legislative experiments, some one compares many classes together, generalizes the results, and proposes to be guided by the generalization, he shakes his head skeptically. And his skepticism passes into ridicule if it is proposed to affiliate such generalized results on the laws of Mind. To prescribe for society on the strength of countless unclassified observations, appears to him a sensible course; but, to colligate and systematize the observations so as to educe tendencies of human behavior displayed throughout cases of numerous kinds, to trace these tendencies to their sources in the mental natures of men, and thence to draw conclusions for guidance, appears to him a visionary course.

Let us look at some of the fundamental facts he ignores, and at the results of ignoring them.

Rational legislation, based as it can only be on a true theory of conduct, which is derivable only from a true theory of mind, must recognize as a datum the direct connection of action with feeling. That feeling and action bear a constant ratio, is a statement needing qualification; for at the one extreme there are automatic actions which take place without feeling, and at the other extreme there are feelings so intense that, by deranging the vital functions, they impede or arrest action. But, speaking of those activities which life in general presents, it is a law tacitly recognized by all, though not distinctly formulated, that action and feeling vary together in their amounts. Passivity and absence of facial expression, both implying rest of the muscles, are held to show that there is being experienced neither much sensation nor much emotion, while the degree of external demonstration, be it in movements that rise finally to spasms and contortions, or be it in sounds that end in laughter, and shrieks, and groans, is habitually accepted as a measure of the pleasure or pain, sensational or emotional. And so, too, where continued expenditure of energy is seen, be it in a violent struggle to escape, or be it in the persevering pursuit of an object, the quantity of effort is held to show the quantity of feeling.

This truth, undeniable in its generality, whatever qualifications secondary truths make in it, must be joined with the truth that cognition does *not* produce action. If I tread on a pin, or unawares dip my hand into very hot water, I start: the strong sensation produces motion without any thought intervening. Conversely, the proposition that a pin pricks, or that hot water scalds, leaves me quite unmoved. True, if to one of these propositions is joined the idea that a pin is about to pierce my skin, or to the other the idea that some hot water will fall on it, there results a tendency, more or less decided, to shrink. But that which causes shrinking is the ideal pain. The statement that the pin will hurt or the water scald produces no effect, so long as there is nothing beyond a recognition of its meaning: it produces an effect only when the pain verbally asserted becomes a pain actually conceived as impending—only when there rises in consciousness a representation of the pain, which is a faint form of the pain as before felt. That is to say, the cause of movement here, as in other cases, is a feeling and not a cognition. What we see even in these simplest actions, runs through actions of all degrees of complexity. It is never the knowledge which is the moving agent in conduct, but it is always the feeling which goes along with that knowledge, or is excited by it. Though the drunkard knows that after to-day's debauch will come to-morrow's headache, yet he is not deterred by consciousness of this truth, unless the penalty is distinctly represented—unless there rises in his consciousness a vivid idea of the misery to be borne—unless there is excited in him an adequate amount of feeling antagonistic to his desire for drink. Similarly with improvidence in general. If coming evils are imagined with clearness and the threatened sufferings ideally felt, there is a due check on the tendency to take immediate gratifications without stint; but, in the absence of that consciousness of future ills which is constituted by the ideas of pains, distinct or vague, the passing desire is not opposed effectually. The truth that recklessness brings distress, fully acknowledged though it may be, remains inoperative. The mere cognition does not affect conduct—conduct is affected only when the cognition passes out of that intellectual form in which the idea of distress is little more than verbal, into a form in which this term of the proposition is developed into a vivid imagination of distress—a mass of painful feeling. It is thus with conduct of every kind. See this group of persons clustered at the river-side. A boat has upset, and some one is in danger of drowning. The fact, that, in the absence of aid, the youth in the water will shortly die, is known to them all. That by swimming to his assistance his life may be saved, is a proposition denied by none of them. The duty of helping fellow-creatures who are in difficulties, they have been taught all their lives; and they will severally admit that running a risk to prevent a death is praiseworthy. Nevertheless, though sundry of them can swim, they do nothing beyond shouting for assistance or giving advice. But now here comes one who, tearing off his coat, plunges in to the rescue. In what does he differ from the others? Not in knowledge. Their cognitions are equally clear with his. They know as well as he does that death is impending, and know, too, how it may be prevented. In him, however, these cognitions arouse certain correlative emotions more strongly than they are aroused in the rest. Groups of feelings are excited in all; but, whereas in the others the deterrent feelings of fear, etc., preponderate, in him there is a surplus of the feelings excited by sympathy, joined, it may be, with others not of so high a kind. In each case, however, the behavior is not determined by knowledge, but by emotion. Obviously, change in the actions of these passive spectators is not to be effected by making their cognitions clearer, but by making their higher feelings stronger.

Have we not here, then, a cardinal psychological truth, to which any rational system of human discipline must conform? Is it not manifest that a legislation which ignores it and tacitly assumes its opposite will inevitably fail? Yet much of our legislation does this; and we are at present, legislature and nation together, eagerly pushing forward schemes which proceed on the postulate that conduct is determined not by feelings, but by cognitions.

For what else is the assumption underlying this anxious urging-on of organizations for teaching? What is the root-notion common to Secularists and Denominationalists, but the notion that spread of knowledge is the one thing needful for bettering behavior? Having both swallowed certain statistical fallacies, there has grown up in them the belief that State-education will check ill-doing. In newspapers, they have often met with comparisons between the numbers of criminals who can read and write and the numbers who cannot; and, finding the numbers who cannot greatly exceed the numbers who can, they accept the inference that ignorance is the cause of crime. It does not occur to them to ask whether other statistics, similarly drawn up, would not prove with like conclusiveness that crime is caused by absence of ablutions, or by lack of clean linen, or by bad ventilation, or by want of a separate bedroom. Go through any jail, and ascertain how many prisoners had been in the habit of taking a morning bath, and you would find that criminality habitually went with dirtiness of skin. Count up those who had possessed a second suit of clothes, and a comparison of the figures would show you that but a small percentage of criminals were habitually able to change their garments. Inquire whether they had lived in main streets or down courts, and you would discover that nearly all urban crime comes from holes and corners. Similarly, a fanatical advocate of total abstinence or of sanitary improvement could get equally strong statistical justifications for his belief. But, if, not accepting the random inference presented to you, that ignorance and crime are cause and effect, you consider, as above, whether crime may not with equal reason be ascribed to various other causes, you are led to see that it is really connected with an inferior mode of life, itself usually consequent on original inferiority of nature; and you are led to see that ignorance is simply one of the concomitants, no more to be held the cause of crime than various other concomitants.

But this obvious criticism, and the obvious counter-conclusion it implies, are not simply overlooked, but, when insisted on, seem powerless to affect the belief which has taken possession of men. Disappointment alone will now affect it. A wave of opinion, reaching a certain height, cannot be changed by any evidence or argument, but has to spend itself in the gradual course of things before a reaction of opinion can arise. Otherwise it would be incomprehensible that this confidence in the curative effects of teaching, which men have carelessly allowed to be generated in them by the reiterations of *doctrinaire* politicians, should survive the direct disproofs yielded by daily experience. Is it not the trouble of every mother and every governess, that perpetual insisting on the right and denouncing the wrong do not suffice? Is it not the constant complaint that on many natures reasoning and explanation and the clear demonstration of consequences are scarcely at all operative; that where they are operative there is a more or less marked difference of emotional nature; and that where, having before failed, they begin to succeed, change of feeling rather than difference of apprehension is the cause? Do we not similarly hear from every house-keeper that servants usually pay but little attention to reproofs; that they go on perversely in old habits, regardless of clear evidence of their foolishness; and that their actions are to be altered not by explanations and reasonings, but by either the fear of penalties or the experience of penalties—that is, by the emotions awakened in them? When we turn from domestic life to the life of the outer world, do not like disproofs everywhere meet us? Are not fraudulent bankrupts educated people, and getters-up of bubble-companies, and makers of adulterated goods, and users of false trade-marks, and retailers who have light weights, and owners of unseaworthy ships, and those who cheat insurance-companies, and those who carry on turf-chicaneries, and the great majority of gamblers? Or, to take a more extreme form of turpitude—is there not, among those who have committed murder by poison within our memories, a considerable number of the educated—a number bearing as large a ratio to the educated classes as does the total number of murderers to the total population?

This belief in the moralizing effects of intellectual culture, flatly contradicted by facts, is absurd *a priori*. What imaginable connection is there between the learning that certain clusters of marks on paper stand for certain words and the getting a higher sense of duty? What possible effect can acquirement of facility in making written signs of sounds have in strengthening the desire to do right? How does knowledge of the multiplication-table, or quickness in adding and dividing, so increase the sympathies as to restrain the tendency to trespass against fellow-creatures? In what way can the attainment of accuracy in spelling and parsing, etc., make the sentiment of justice more powerful than it was; or why from stores of geographical information, perseveringly gained, is there likely to come increased regard for truth? The irrelation between such causes and such effects is almost as great as that between exercise of the fingers and strengthening of the legs. One who should by lessons in Latin hope to give a knowledge of geometry, or one who should expect practice in drawing to be followed by expressive rendering of a sonata, would be thought fit for an asylum; and yet he would be scarcely more irrational than are those who by discipline of the intellectual faculties expect to produce better feelings.

This faith in lesson-books and readings is one of the superstitions of the age. Even as appliances to intellectual culture, books are greatly over-estimated. Instead of second-hand knowledge being regarded as of less value than first-hand knowledge, and as a knowledge to be sought only where first-hand knowledge cannot be had, it is actually regarded as of greater value. Something gathered from printed pages is supposed to enter into a course of education; but, if gathered by observation of Life and Nature, is supposed not thus to enter. Reading is seeing by proxy—is learning indirectly through another man's faculties, instead of directly through one's own faculties; and such is the prevailing bias that the indirect learning is thought preferable to the direct learning, and usurps the name of cultivation! We smile when told that savages consider writing as a kind of magic: and we laugh at the story of the negro who hid a letter under a stone, that it might not inform against him when he devoured the fruit he was sent with. Yet the current notions about printed information betray a kindred delusion: a kind of magical efficacy is ascribed to ideas gained through artificial appliances, as compared with ideas otherwise gained. And this delusion, injurious in its effects even on intellectual culture, produces effects still more injurious on moral culture, by generating the assumption that this, too, can be got by reading and the repeating of lessons.

It will, I know, be said that not from intellectual teaching, but from moral teaching, are improvement of conduct and diminution of crime looked for. While, unquestionably, many of those who urge on educational schemes believe in the moralizing effects of knowledge in general, it must be admitted that some hold general knowledge to be inadequate, and contend that rules of right conduct must be taught. Already, however, reasons have been given why the expectations even of these are illusory; proceeding, as they do, on the assumption that the intellectual acceptance of moral precepts will produce conformity to them. Plenty more reasons are forthcoming. I will not dwell on the contradictions to this assumption furnished by the Chinese, to all of whom the high ethical maxims of Confucius are taught, and who yet fail to show us a conduct proportionately exemplary. Nor will I enlarge on the lesson to be derived from the United States, the school-system of which brings up the whole population under the daily influence of chapters which set forth principles of right conduct, and which nevertheless in its political life, and by many of its social occurrences, shows us that conformity to these principles is any thing but complete. It will suffice if I limit myself to evidence supplied by our own society, past and present, which negatives, very decisively, these sanguine expectations. For, what have we been doing all these many centuries by our religious agencies, but preaching right principles to old and young? What has been the aim of services in our ten thousand churches, week after week, but to enforce a code of good conduct by promised rewards and threatened penalties?—the whole population having been for many generations compelled to listen. What have Dissenting chapels, more numerous still, been used for, unless as places where pursuance of right and desistance from wrong have been unceasingly commended to all from childhood upward? And if now it is held that something more must be done—if, notwithstanding perpetual explanations and denunciations and exhortations, the misconduct is so great that society is endangered, why, after all this insistance has failed, is it expected that more insistance will succeed? See here the proposals and the implied beliefs. Teaching by clergymen not having had the desired effect, let us try teaching by school-masters. Bible-reading from a pulpit, with the accompaniment of imposing architecture, painted windows, tombs, and "dim religious light," having proved inadequate, suppose we try bible-reading in rooms with bare walls, relieved only by maps and drawings of animals. Commands and interdicts, uttered by a surpliced priest to minds prepared by chant and organ-peal, not having been obeyed, let us see whether they will be obeyed when mechanically repeated in school-boy sing-song to a threadbare usher, amid the buzz of lesson-learning and clatter of slates. No very hopeful proposals, one would say; proceeding, as they do, upon one or other of the beliefs, that a moral precept will be effective in proportion as it is received without emotional accompaniment, and that its effectiveness will increase in proportion to the number of times it is repeated. Both these beliefs are directly at variance with the results of psychological analysis and of daily experience. Certainly, such influence as may be gained by addressing moral truths to the intellect, is made greater if the accompaniments arouse an appropriate emotional excitement, as a religious service does; while, conversely, there can be no more effectual way of divesting such moral truths of their impressiveness, than associating them with the prosaic and vulgarizing sounds and sights and smells coming from crowded children. And no less certain is it that precepts, often heard and little regarded, lose by repetition the small influence they had. What do public-schools show us?—are the boys rendered merciful to one another by listening to religious injunctions every morning? What do universities show us?—have perpetual chapels habitually made undergraduates behave better than the average of young men? What do cathedral-towns show us?—is there in them a moral tone above that of other towns, or must we from the common saying, "the nearer the church," etc., infer a pervading impression to the contrary? What do clergymen's sons show us?—has constant insistance on right conduct made them conspicuously superior, or do we not rather hear it whispered that something like an opposite effect seems produced. Or, to take one more case, what do religious newspapers show us?—is it that the precepts of Christianity, more familiar to their writers than to other writers, are more clearly to be traced in their articles, or has there not ever been displayed a want of charity in their dealings with opponents, and is it not still displayed? Nowhere do we find that repetition of rules of right, already known but disregarded, produces regard for them; but we find that, contrariwise, it makes the regard for them less than before.

The prevailing assumption is, indeed, as much disproved by analysis as it is contradicted by familiar facts. Already we have seen that the connection is between action and feeling; and hence the corollary, that only by a frequent passing of feeling into action is the tendency to such action strengthened. Just as two ideas often repeated in a certain order become coherent in that order; and just as muscular motions, at first difficult to combine properly with one another and with guiding perceptions, become by practice facile, and at length automatic; so the recurring production of any conduct by its prompting emotion makes that conduct relatively easy. Not by precept, though heard daily; not by example, unless it is followed; but only by action, often caused by the related feeling, can a moral habit be formed. And yet this truth, which Mental Science clearly teaches, and which is in harmony with familiar sayings, is a truth wholly ignored in current educational fanaticisms.

There is ignored, too, the correlative truth; and ignoring it threatens results still more disastrous. While we see an expectation of benefits which the means used cannot achieve, we see no consciousness of injuries which will be entailed by these means. As usually happens with those absorbed in the eager pursuit of some good by governmental action, there is a blindness to the evil reaction on the natures of citizens. Already the natures of citizens have suffered from kindred reactions, due to actions set up centuries ago; and now the mischievous effects are to be increased by further such reactions.

The English people are complained of as improvident. Very few of them lay by in anticipation of times when work is slack; and the general testimony is that higher wages commonly result only in more extravagant living or in drinking to greater excess. As we saw a while since, they neglect opportunities of becoming shareholders in the companies they are engaged under; and those who are most anxious for their welfare despair on finding how little they do to raise themselves when they have the means. This tendency to seize immediate gratification regardless of future penalty is commented on as characteristic of the English people; and, contrasts between them and their Continental neighbors having been drawn, surprise is expressed that such contrasts should exist. Improvidence is spoken of as an inexplicable trait of the race—no regard being paid to the fact that races with which it is compared are allied in blood. The people of Norway are economical and extremely prudent. The Danes, too, are thrifty; and Defoe, commenting on the extravagance of his countrymen, says that a Dutchman gets rich on wages out of which an Englishman but just lives. So, too, if we take the modern Germans. Alike by the complaints of the Americans, that the Germans are ousting them from their own businesses by working hard and living cheaply, and by the success here of German traders and the preference shown for German waiters, we are taught that in other divisions of the Teutonic race there is nothing like this lack of self-control. Nor can we ascribe to such portion of Norman blood as exists among us this peculiar trait: descendants of the Normans in France are industrious and saving. Why, then, should the English people be improvident? If we seek explanation in their remote lineage, we find none; but, if we seek it in the social conditions to which they have been subject, we find a sufficient explanation. The English are improvident because they have been for ages disciplined in improvidence. Extravagance has been made habitual by shielding them from the sharp penalties extravagance brings. Carefulness has been discouraged by continually showing to the careful that those who were careless did as well as, or better than, themselves. Nay, there have been positive penalties on carefulness. Laborers working hard and paying their way have constantly found themselves called on to help in supporting the idle around them ; have had their goods taken under distress-warrants that paupers might be fed ; and eventually have found themselves and their children reduced also to pauperism. Well-conducted poor women, supporting themselves without aid or encouragement, have seen the ill-conducted receiving parish-pay for their illegitimate children. Nay, to such extremes has the process gone, that women with many illegitimate children, getting from the rates a weekly sum for each, have been chosen as wives by men who wanted the sums thus derived ! Generation after generation the honest and independent, not marrying till they had means, and striving to bring up their families without assistance, have been saddled with extra burdens, and hindered from leaving a desirable posterity ; while the dissolute and the idle, especially when given to that lying and servility by which those in authority are deluded, have been helped to produce and to rear progeny, characterized, like themselves, by absence of the mental traits needed for good citizenship. And then, after centuries during which we have been breeding the race as much as possible from the improvident, and repressing the multiplication of the provident, we lift our hands and exclaim at the recklessness our people exhibit ! If men, who, for a score of generations, had by preference bred from their worst-tempered horses and their least-sagacious dogs, were then to wonder because their horses were vicious and their dogs stupid, we should think the absurdity of their policy paralleled only by the absurdity of their astonishment ; but human beings instead of inferior animals being in question, no absurdity is seen either in the policy or in the astonishment.

And now something more serious happens than the overlooking of these evils wrought on men's natures by centuries of demoralizing influences. We are deliberately establishing further such influences. Having, as much as we could, suspended the civilizing discipline of an industrial life so carried on as to achieve self-maintenance without injury to others, we now proceed to suspend that civilizing discipline in another direction. Having in successive generations done our best to diminish the sense of responsibility, by warding off evils which disregard of responsibility brings, we now carry the policy further by relieving parents from certain other responsibilities which, in the order of Nature, fall on them. By way of checking recklessness, and discouraging improvident marriages, and raising the conception of duty, we are diffusing the belief that it is not the concern of parents to fit their children for the business of life; but that the nation is bound to do this. Everywhere there is a tacit enunciation of the marvellous doctrine that citizens are not responsible individually for the bringing up each of his own children, but that these same citizens, incorporated into a society, are each of them responsible for the bringing up of everybody else's children! The obligation does not fall upon A in his capacity of father to rear the minds as well as the bodies of his offspring; but in his capacity of citizen there does fall on him the obligation of mentally rearing the offspring of B, C, D, and the rest, who similarly have their direct parental obligations made secondary to their indirect obligations to children not their own! Already it is estimated that, as matters are now being arranged, parents will soon pay in school-fees for their own children only one-sixth of the amount which is paid by them through taxes, rates, and voluntary contributions, for children at large: in terms of money, the claims of children at large to their care will be taken as six times the claim of their own children! And, if, looking back forty years, we observe the growth of the public claim *versus* the private claim, we may infer that the private claim will presently be absorbed wholly. Already the correlative theory is becoming so definite and positive that you meet with the notion, uttered as though it were an unquestionable truth, that criminals are "society's failures." Presently it will be seen that, since good bodily development, as well as good mental development, is a prerequisite to good citizenship (for without it the citizen cannot maintain himself, and so avoid wrong-doing), society is responsible also for the proper feeding and clothing of children: indeed, in school-board discussions, there is already an occasional admission that no logically-defensible halting-place can be found between the two. And so we are progressing toward the wonderful notion, here and there finding tacit expression, that people are to marry when they feel inclined, and other people are to take the consequences!

And this is thought to be the policy conducive to improvement of behavior. Men who have been made improvident by shielding them from many of the evil results of improvidence are now to be made more provident by further shielding them from the evil results of improvidence. Having had their self-control decreased by social arrangements which lessened the need for self-control, other social arrangements are devised which will make self-control still less needful: and it is hoped so to make self-control greater. This expectation is absolutely at variance with the whole order of things. Life of every kind, human included, proceeds on an exactly-opposite principle. All lower types of beings show us that the rearing of offspring affords the highest discipline for the faculties. The parental instinct is everywhere that which calls out the energies most persistently, and in the greatest degree exercises the intelligence. The self-sacrifice and the sagacity which inferior creatures display in the care of their young are often commented upon; and every one may see that parenthood produces a mental exaltation not otherwise producible. That it is so among mankind is daily proved. Continually we remark that men who were random grow steady when they have children to provide for; and vain, thoughtless girls, becoming mothers, begin to show higher feelings, and capacities that were not before drawn out. In both there is a daily discipline in unselfishness, in industry, in foresight. The parental relation strengthens from hour to hour the habit of postponing immediate ease and egoistic pleasure to the altruistic pleasure obtained by furthering the welfare of offspring. There is a frequent subordination of the claims of self to the claims of fellow-beings; and by no other agency can the practice of this subordination be so effectually secured. Not, then, by a decreased, but by an increased, sense of parental responsibility is self-control to be made greater and recklessness to be checked. And yet the policy now so earnestly and undoubtingly pursued is one which will inevitably diminish the sense of parental responsibility. This all-important discipline of parents' emotions is to be weakened that children may get reading, and grammar, and geography, more generally than they would otherwise do. A superficial intellectualization is to be secured at the cost of a deep-seated demoralization.

Few, I suppose, will deliberately assert that information is important and character relatively unimportant. Every one observes from time to time how much more valuable to himself and others is the workman who, though unable to read, is diligent, sober, and honest, than is the well-taught workman who breaks his engagements, spends days in drinking, and neglects his family. And, comparing members of the upper classes, no one doubts that the spendthrift or the gambler, however good his intellectual training, is inferior as a social unit to the man who, not having passed through the approved curriculum, nevertheless prospers by performing well the work he undertakes, and provides for his children instead of leaving them in poverty to the care of relatives. That is to say, looking at the matter in the concrete, all see that, for social welfare, good character is more important than much knowledge. And yet the manifest corollary is not drawn. What effect will be produced on character by artificial appliances for spreading knowledge is not asked. Of the ends to be kept in view by the legislator, all are unimportant compared with the end of character-making; and yet character-making is an end wholly unrecognized.

Let it be seen that the future of a nation depends on the natures of its units; that their natures are inevitably modified in adaptation to the conditions in which they are placed; that the feelings called into play by these conditions will strengthen, while those which have diminished demands on them will dwindle; and it will be seen that the bettering of conduct can be effected, not by insisting on maxims of good conduct, still less by mere intellectual culture, but only by that daily exercise of the higher sentiments and repression of the lower, which results from keeping men subordinate to the requirements of orderly social life—letting them suffer the inevitable penalties of breaking these requirements, and reap the benefits of conforming to them. This alone is national education.

A NATIONAL UNIVERSITY.[1]

By CHARLES W. ELIOT,
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I TURN next to my third topic, the true policy of our government as regards university instruction. In almost all the writings about a nation's university, and of course in the two Senate bills now under discussion, there will be found the implication, if not the express assertion, that it is somehow the duty of our government to maintain a magnificent university. This assumption is the foundation upon which rest the ambitious projects before us, and many similar schemes. Let me try to demonstrate that the foundation is itself unsound.

The general notion that a beneficent government should provide and control an elaborate organization for teaching, just as it maintains an army, a navy, or a post-office, is of European origin, being a legitimate corollary to the theory of government by divine right. It is said that the state is a person having a conscience and a moral responsibility; that the government is the visible representative of a people's civilization, and the guardian of its honor and its morals, and should be the embodiment of all that is high and good in the people's character and aspirations. This moral person, this corporate representative of a Christian nation, has high duties and functions commensurate with its great powers, and none more imperative than that of diffusing knowledge and advancing science.

I desire to state this argument for the conduct of high educational institutions by government, as a matter of abstract duty, with all the force which belongs to it; for, under an endless variety of thin disguises, and with all sorts of amplifications and dilutions, it is a staple commodity with writers upon the relation of government to education. The conception of government upon which this argument is

[1] Closing argument of a report by President Eliot to the National Educational Association at its recent session in Elmira. The first part of the report gives an account of what had been done by the Association about the project of a national university since 1869; and the second part examines the two bills on the subject which were brought before Congress in 1872.

based is obsolescent everywhere. In a free community the government does not hold this parental, or patriarchal—I should better say godlike—position. Our government is a group of servants appointed to do certain difficult and important work. It is not the guardian of the nation's morals; it does not necessarily represent the best virtue of the republic, and is not responsible for the national character, being itself one of the products of that character. The doctrine of state personality and conscience, and the whole argument of the dignity and moral elevation of a Christian nation's government as the basis of government duties, are natural enough under grace-of-God governments, but they find no ground of practical application to modern republican confederations; they have no bearing on governments considered as purely human agencies with defined powers and limited responsibilities. Moreover, for most Americans these arguments prove a great deal too much; for, if they have the least tendency to persuade us that government should direct any part of secular education, with how much greater force do they apply to the conduct by government of the religious education of the people! These propositions are, indeed, the main arguments for an established church. Religion is the supreme human interest, government is the supreme human organization; therefore, government ought to take care for religion, and a Christian government should maintain distinctively Christian religious institutions. This is not theory alone; it is the practice of all Christendom, except in America and Switzerland. Now, we do not admit it to be our duty to establish a national church. We believe not only that our people are more religious than many nations which have established churches, but also that they are far more religious under their own voluntary system than they would be under any government establishment of religion. We do not admit for a moment that establishment or no establishment is synonymous with national piety or impiety. Now, if a beneficent Christian government may rightly leave the people to provide themselves with religious institutions, surely it may leave them to provide suitable universities for the education of their youth. And here again the question of national university or no national university is by no means synonymous with the question, Shall the country have good university education or not? The only question is, Shall we have a university supported and controlled by government, or shall we continue to rely upon universities supported and controlled by other agencies?

There is, then, no foundation whatever for the assumption that it is the duty of our government to establish a national university. I venture to state one broad reason why our government should not establish and maintain a university. If the people of the United States have any special destiny, any peculiar function in the world, it is to try to work out under extraordinarily favorable circumstances the problem of free institutions for a heterogeneous, rich, multitudinous population, spread over a vast territory. We, indeed, want to breed scholars, artists, poets, historians, novelists, engineers, physicians, jurists, theologians, and orators; but, first of all, we want to breed a race of independent, self-reliant freemen, capable of helping, guiding, and governing themselves. Now, the habit of being helped by the government, even if it be to things good in themselves—to churches, universities, and railroads—is a most insidious and irresistible enemy of republicanism; for the very essence of republicanism is self-reliance. With the Continental nations of Europe it is an axiom that the government is to do every thing, and is responsible for every thing. The French have no word for "public spirit," for the reason that the sentiment is unknown to them. This abject dependence on the government is an accursed inheritance from the days of the divine right of kings. Americans, on the contrary, maintain precisely the opposite theory—namely, that government is to do nothing not expressly assigned it to do, that it is to perform no function which any private agency can perform as well, and that it is not to do a public good even, unless that good be otherwise unattainable. It is hardly too much to say that this doctrine is the foundation of our public liberty. So long as the people are really free they will maintain it in theory and in practice. During the war of the rebellion we got accustomed to seeing the government spend vast sums of money and put forth vast efforts, and we asked ourselves, Why should not some of these great resources and powers be applied to works of peace, to creation as well as to destruction? So we subsidized railroads and steamship companies, and agricultural colleges, and now it is proposed to subsidize a university. The fatal objection to this subsidizing process is that it saps the foundations of public liberty. The only adequate securities of public liberty are the national habits, traditions, and character, acquired and accumulated in the practice of liberty and self-control. Interrupt these traditions, break up these habits or cultivate the opposite ones, or poison that national character, and public liberty will suddenly be found defenceless. We deceive ourselves dangerously when we think or speak as if education, whether primary or university, could guarantee republican institutions. Education can do no such thing. A republican people should, indeed, be educated and intelligent; but it by no means follows that an educated and intelligent people will be republican. Do I seem to conjure up imaginary evils to follow from this beneficent establishment of a superb national university? We teachers should be the last people to forget the sound advice—*obsta principiis.* A drop of water will put out a spark which otherwise would have kindled a conflagration that rivers could not quench.

Let us cling fast to the genuine American method—the old Massachusetts method—in the matter of public instruction. The essential features of that system are local taxes for universal elementary education voted by the citizens themselves, local elective boards to spend the money raised by taxation and control the schools, and for the higher grades of instruction permanent endowments administered by incorporated bodies of trustees. This is the American voluntary system, in sharp contrast with the military, despotic organization of public instruction which prevails in Prussia and most other states of Continental Europe. Both systems have peculiar advantages, the crowning advantage of the American method being that it breeds freemen. Our ancestors well understood the principle that, to make a people free and self-reliant, it is necessary to let them take care of themselves, even if they do not take quite as good care of themselves as some superior power might.

And now, finally, let us ask what should make a university at the capital of the United States, established and supported by the General Government, more national than any other American university. It might be larger and richer than any other, and it might not be; but certainly it could not have a monopoly of patriotism or of catholicity, or of literary or scientific enthusiasm. There are an attractive comprehensiveness and a suggestion of public spirit and love of country in the term "national;" but, after all, the adjective only narrows and belittles the noble conception contained in the word "university." Letters, science, art, philosophy, medicine, law, and theology, are larger and more enduring than nations. There is something childish in this uneasy hankering for a big university in America, as there is also in that impatient longing for a distinctive American literature which we so often hear expressed. As American life grows more various and richer in sentiment, passion, thought, and accumulated experience, American literature will become richer and more abounding, and in that better day let us hope that there will be found several universities in America, though by no means one in each State, as free, liberal, rich, national, and glorious, as the warmest advocate of a single crowning university at the national capital could imagine his desired institution to become.

AGASSIZ AND DARWINISM.

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ONE Friday morning, a few weeks ago, as I was looking over the *Nation*, my eye fell upon an advertisement, inserted by the proprietors of the *New-York Tribune*, announcing the final destruction of Darwinism. What especially riveted my attention was the peculiar style of the announcement: "The Darwinian Theory utterly demolished" (or words to that effect) "by AGASSIZ HIMSELF!" Whether from accident or design, the type-setter's choice of Roman capitals was very happy. Upon many readers the effect must have been tremendous; and quite possibly there may be some who, without further investigation, will carry to their dying day the opinion that it is all over with the Darwinian theory, since "Agassiz Himself" has refuted it.

Upon me the effect was such as to make me lay down my paper and ask myself: Can it be that we have, after all, a sort of scientific pope among us? Has it come to this, that the dicta of some one "servant and interpreter of Nature" are to be accepted as final, even against the better judgment of the majority of his compeers? In short, who is Agassiz himself, that he should thus single-handed have demolished the stoutest edifice which observation and deduction have reared since the day when Newton built to such good purpose?

Prof. Agassiz is a naturalist who is justly world-renowned for his achievements. His contributions to geology, to paleontology, and to systematic zoology, have been such as to place him in a very high rank among contemporary naturalists. Not quite in the highest place, I should say; for, apart from all questions of theory, it is probable that Mr. Darwin's gigantic industry, his wonderful thoroughness and accuracy as an observer, and his unrivalled fertility of suggestion, will cause him in the future to be ranked along with Aristotle, Linnæus, and Cuvier; and upon this high level we cannot place Prof. Agassiz. Leaving Mr. Darwin out of the account, we may say that Prof. Agassiz stands in the first rank of contemporary naturalists. But any exceptional supremacy in this first rank can by no means be claimed for him. Both for learning and for sagacity, the names of Gray, Wyman, Huxley, Hooker, Wallace, Lubbock, Lyell, Vogt, Haeckel, and Gegenbaur, are quite as illustrious as the name of Agassiz; and we may note, in passing, that these are the names of men who openly indorse and defend the Darwinian theory.

Possibly, however, there are some who will not be inclined to accept the estimates made in the foregoing paragraph. No doubt there are many people in this country who have long accustomed themselves to regard Prof. Agassiz not simply as one among a dozen or twenty living naturalists of the highest rank, but as occupying a solitary position as the greatest of all living naturalists—as a kind of second Cuvier, for example. There is, to the popular eye, a halo about the name of Agassiz which there is not about the name of Gray; though, if there is any man now living in America, of whom America might justly boast as her chief ornament and pride, so far as science is concerned, that man is unquestionably Prof. Asa Gray. Now, this greater popular fame of Agassiz is due to the fact that he is a European who cast in his lot with us at a time when we were wont to over-rate foreign importations of whatever sort. As a European, therefore, he outshines such men as Profs. Gray and Wyman, and, as a man whom we know, he outshines other Europeans, like Haeckel and Gegenbaur, whose acquaintance we happen not to have made; just as Rubinstein, whose fame has filled the American newspapers, outshines Bülow (probably his equal as a pianist), who has not yet visited this country. In this way Prof. Agassiz has acquired a reputation in America which is greater than his reputation in Europe, and which is greater than his achievements—admirable as they are—would be able, on trial, to sustain.

And now I come to my first point. Admitting for Prof. Agassiz all the wonderful greatness as a naturalist with which the vague sentiments of the uneducated multitude in this country would accredit him; admitting, in other words, that he is the greatest of naturalists, and not one among a dozen or twenty equals; it must still be asked, why should his rejection of Darwinism be regarded as conclusively fatal to the Darwinian theory? The history of science supplies us with many an instance in which a new and unpopular theory has been vehemently opposed by those whom one would at first suppose most competent to judge of its merits, and has nevertheless gained the victory. Dr. Draper brings a terrible indictment against Bacon for rejecting the Copernican theory, and refusing to profit by the discoveries of Gilbert in magnetism. This should not be allowed to detract from Bacon's real greatness, any more than the rejection of Darwinism should be allowed to detract from the real merit of Agassiz. Great men must be measured by their positive achievements rather than by their negative shortcomings, otherwise they might all have to step down from their pedestals. Leibnitz rejected Newton's law of gravitation; Harvey saw nothing but foolishness in Aselli's discovery of the lacteals; Magendie ridiculed the great work in which the younger Geoffroy Saint-Hilaire began to investigate the conditions of nutrition which determine the birth of monsters; and when Young, Fresnel, and Malus, completed the demonstration of that undulatory theory of light which has made their names immortal, Laplace, nevertheless, the greatest mathematician of the age, persisted until his dying day in heaping contumely upon these eminent men and upon their arguments. Nay, even Cuvier—the teacher whom Prof. Agassiz so justly reveres—did not Cuvier adhere to the last to the grotesque theory of "pre-formation," and reject the true theory of "epigenesis," which C. F. Wolff, even before Baer, had placed upon a scientific basis? Supposing, then, that the Darwinian theory is rejected by Agassiz, this fact is no more decisive against the Darwinian theory than the rejection of Fresnel's theory by Laplace was decisive against Fresnel's theory.

For the facts just cited show that even the wisest and most learned men are not infallible, and that it will not do to have a papacy where scientific questions are concerned. Strange as it may at first seem, nothing is more certain than that a man's opinion may be eminently fallible, even with reference to matters which might appear to come directly within the range of his own specialty. Many people, I presume, think that, because Prof. Agassiz has made a specialty of the study of extinct and living organisms, because he has devoted a long and industrious life to this study, therefore his opinion with reference to the relations of present life upon the globe to past life ought to be at once conclusive. The fallacy of this inference becomes apparent as soon as we recollect that Profs. Gray, Wyman, Huxley, and Haeckel, who are equally well qualified to have an opinion on such matters, have agreed in forming an opinion diametrically opposite to that of Prof. Agassiz. But the fallacy may be shown independently of any such comparison. Even if all the foundations of certainty seem to be shaking beneath us when we say that an expert is not always the best judge of matters pertaining to his own specialty, we must still say it, for facts will bear us out in saying it. I have known excellent mathematicians and astronomers who had not the first word to say about the Nebular Hypothesis: they had never felt interested in it, had never studied it, and consequently did not understand it, and could hardly state it correctly. After a while one ceases to be surprised at such things. It is quite possible for one to study the structure of echinoderms and fishes during a long life, and yet remain unable to offer a satisfactory opinion upon any subject connected with zoology, for the proper treatment of which there are required some power of generalization and some familiarity with large considerations. Indeed, there are many admirable experts in natural history, as well as in other studies, who never pay the slightest heed to questions involving wide-reaching considerations; and who, with all their amazing minuteness of memory concerning the metamorphoses of insects and the changes which the embryo of a white-fish undergoes from fecundation to maturity, are nevertheless unable to see the evidentiary value of the great general facts of geological succession and geographical distribution, even when it is thrust directly before their eyes. To such persons, "science" means the collecting of polyps, the dissecting of mollusks, the vivisection of frogs, the registration of innumerable facts of detail, without regard to the connected story which all these facts, when put together, have it in their power to tell. And all putting together of facts, with a view to elicit this connected story, they are too apt to brand as unscientific speculation; forgetting that if Newton had merely occupied himself with taking observations and measuring celestial distances, instead of propounding an audacious hypothesis, and then patiently verifying it, the law of gravitation might never have been discovered. Herein lies the explanation of the twice-repeated rejection of Mr. Darwin's name by the French Academy of Sciences. The lamentable decline of science in France since the beginning of the Second Empire has been most conspicuously marked by the tendency of scientific inquirers to occupy themselves exclusively with matters of detail, to the neglect of wide-reaching generalizations. And the rejection of Mr. Darwin's name was justified upon the ground, not that he had made unscientific generalizations, but that he had been a *mere* (!) generalizer, instead of a collector of facts. The allegation was, indeed, incorrect; since Mr. Darwin is as eminent for his industry in collecting facts as for his boldness in generalizing. But the form of the allegation well illustrates the truth of what I have been seeking to show—that familiarity with the details of a subject does not enable one to deal with it in the grand style, and elicit new truth from old facts, unless one also possesses some faculty for penetrating into the hidden implications of the facts; or, in other words, some faculty for philosophizing.

Now, I am far from saying of Prof. Agassiz that he is a mere collector of echinoderms and dissector of fishes, with no tact whatever in philosophizing. He does not stand in the position of those who think that the end of scientific research is attained when we have carefully ticketed a few thousand specimens of corals and butterflies, in much the same spirit as that in which a school-girl collects and classifies autographs or postage-stamps. Along with his indefatigable industry as a collector and observer, Prof. Agassiz has a decided inclination toward general views. However lamentably deficient we may think him in his ability to discern the hidden implications of facts, there can be no question that his facts are of little importance to him save as items in a philosophic scheme. He knows very well—perhaps almost too well—that the value of facts lies in the conclusions to which they point. And, accordingly, lack of philosophizing is the last shortcoming with which, as a scientific writer, he can be charged. If he errs on a great scientific question, lying within his own range of investigation, it is not because he refrains steadfastly from all general considerations, but because he philosophizes—and philosophizes on unsound principles. It is because his philosophizing is not a natural outgrowth from the facts of Nature which lie at his disposal, but is made up out of sundry traditions of his youth, which, by dint of playing upon the associations of ideas which are grouped around certain combinations of words, have come to usurp the place of observed facts as a basis for forming conclusions. It is not because he abstains from generalizing that Prof. Agassiz is unable to appreciate the arguments by which Mr. Darwin has established his theory, but it is because he long ago brought his mind to acquiesce in various generalizations, of a thoroughly unscientific or non-scientific character, with the further maintenance of which the acceptance of the Darwinian theory is (or seems to Prof. Agassiz to be) incompatible.

The generalizations which have thus preoccupied Prof. Agassiz's mind are purely theological or mythological in their nature. In estimating the probable soundness of his opinion upon any scientific question, it must always be remembered that he is, above all things, a devotee of what is called "natural theology." In his discussions concerning the character of the relationships between the various members of the animal kingdom, the foreground of his consciousness is always completely occupied by theological considerations, to such an extent that the evidentiary value of scientific facts cannot always get a footing there, and is, consequently, pushed away into the background. One feels, in reading his writings, that, except when he is narrating facts with the pure joyfulness of a specialist exulting in the exposition of his subject (and, when in this mood, he often narrates facts with which his inferences are wholly incompatible), he never makes a point without some regard to its bearings upon theological propositions which his early training has led him to place paramount to all facts of observation whatever. In virtue of this peculiarity of disposition, Prof. Agassiz has become the welcome ally of those zealous but narrow-minded theologians, in whom the rapid progress of the Darwinian theory has awakened the easily explicable but totally groundless fear that the necessary foundations of true religion, or true Christianity, are imperilled. It is not many years since these very persons regarded Prof. Agassiz with dread and abhorrence, because of his flat contradiction of the Bible in his theory of the multiple origin of the human race. But, now that the doctrine of Evolution has come to be the unclean thing above all others to be dreaded and abhorred, this comparatively slight iniquity of Prof. Agassiz has been condoned or forgotten, and, as the great antagonist of Evolution, he is welcomed as the defender of the true Church against her foes.

This preference of theological over scientific considerations once led Prof. Agassiz (if my memory serves me rightly) to use language very unbecoming in a professed student of Nature. Some seven years ago he delivered a course of lectures at the Cooper Union, and in one of these lectures he observed that he *preferred* the theory which makes man out a fallen angel to the theory which makes him out an improved monkey—a remark which was quite naturally greeted with laughter and applause. But the applause was ill-bestowed, for the remark was one of the most degrading which a scientific lecturer could make. A scientific inquirer has no business to have "preferences." Such things are fit only for silly women of society, or for young children who play with facts, instead of making sober use of them. What matters it whether we are pleased with the notion of a monkey-ancestry or not? The end of scientific research is the discovery of truth, and not the satisfaction of our whims or fancies, or even of what we are pleased to call our finer feelings. The proper reason for refusing to accept any doctrine is, that it is inconsistent with observed facts, or with some other doctrine which has been firmly established on a basis of fact. The refusal to entertain a theory because it seems disagreeable or degrading, is a mark of intellectual cowardice and insincerity. In matters of scientific inquiry, it is as grave an offence as the letting one's note go to protest is in matters of business. In saying these things, I do not mean to charge Prof. Agassiz with intellectual cowardice and insincerity, for the remark which I criticise so sharply was not worthy of him, it did not comport with his real character as a student of science, and to judge of him by this utterance alone would be to do him injustice.

It was with the hope of finding some more legitimate objections to the Darwinian theory that I procured the *Tribune's* lecture-sheet containing Prof. Agassiz's twelve lectures on the natural foundations of organic affinity, and diligently searched it from beginning to end. I believe I am truthful in saying that a good staggering objection would have been quite welcome to me, just for the sake of the intellectual stimulus implied in dealing with it, for on this subject my mind was so thoroughly made up thirteen years ago, that the discussion of it, as ordinarily conducted, has long since ceased to have any interest for me. I am just as firmly convinced that the human race is descended from lower animal forms, as I am that the earth revolves in an elliptical orbit about the sun. So completely, indeed, is this proposition wrought in with my whole mental structure, that the negation of it seems to me utterly nonsensical and void of meaning, and I doubt if my mind is capable of shaping such a negation into a proposition which I could intelligently state. To have such deeply-rooted convictions shaken once in a while is, I believe, a very useful and wholesome experiment in mental hygiene. That rigidity of mind which prevents the thorough revising of our opinions is sure, sooner or later, to come upon all of us; but we ought to dread it, as we dread the stagnation of old age or death. For some such reasons as these, I am sure that I should have been glad to find, in the course of Prof. Agassiz's lectures, at least one powerful argument against the interpretation of organic affinities which Mr. Darwin has done so much to establish. I should have been still more glad to find some alternative interpretation proposed which could deserve to be entertained as scientific in character. I am sure no task could be more delightful, or more quickening to one's energies, than that of comparing two alternative theories upon this subject, upon which, thus far, only one has ever been propounded which possesses the marks of a scientific hypothesis. But no such pleasure or profit is in store for any one who studies these twelve lectures of Prof. Agassiz. In all these lectures, there is not a single allusion to Mr. Darwin's name, save once in a citation from another author; there is not the remotest allusion to any of the arguments by which Mr. Darwin has contributed most largely to the establishment of the development theory; nay, there is not a single sentence from which one could learn that Mr. Darwin's books had ever been written, or that the theories which they expound had ever taken shape in the mind of any thinking man. I do not doubt that Prof. Agassiz has, at some time read, or looked over, the "Origin of Species;" but there is not a word in these lectures which might not have been written by one who had never heard of that book, or of the arguments which made the publication of it the beginning of a new epoch in the history of science.

Not only is it that Prof. Agassiz does not attack the Darwinian theory in these lectures; it is also that, until the ninth lecture, he does not allude to the doctrine of Evolution in any way. His first eight lectures consist mostly in an account of the development of the embryo in various animals; and in this we have a pure description of facts with which no one certainly will feel like quarrelling, so far as theories are concerned. He goes to work, very much as Max Müller does, in lecturing about the science of language, when he gives you a maximum of interesting etymologies and a minimum of real philosophizing which goes to the bottom of things. But Prof. Agassiz is not so interesting or so stimulating in his discourse as Max Müller. He does not lead us into pleasant fields of illustration, where we would fain tarry longer, forgetting the main purpose of the discussion in our delight at the unessential matters which occupy our attention. On the contrary, it seems to me that Prof. Agassiz's explanation of the development of eggs is rather tedious and dry, and by no means richly fraught with novel suggestions. The exposition is a commonplace one, such as is good for students in the Museum of Comparative Zoology, who are beginning to study embryology, but there are no features which make it especially interesting or instructive to any one who has already served an apprenticeship in these matters.

In his ninth lecture, Prof. Agassiz begins to make some allusion to the development theory—not to the development theory as it now stands since the publication of the "Origin of Species," but to the development theory as it stood in the days when Prof. Agassiz was a young student, when Cuvier and the elder Geoffroy Saint-Hilaire waged fierce warfare in the French Academy, and when the aged Goethe, sanest and wisest of men, foresaw in the issue of that battle the speedy triumph of the development theory. Beyond this point, I will venture to say, Prof. Agassiz has never travelled. The doctrine of Evolution is still, to him, what it was in those early days; and all the discoveries and reasonings of Mr. Darwin have passed by him unheeded and unnoticed. He arrived too early at that rigidity of mind which prevents us from properly comprehending new theories, and which we should all of us dread.

What, now, is the doctrine which Prof. Agassiz begins to attack, in his ninth lecture, and what is the doctrine which he would propose as a substitute? The doctrine which he attacks is simply this—that all organic beings have come into existence through some natural process of causation; and the doctrine which he defends is just this—that all organic beings, as classed in species, have come into existence at the outset by means of some act of which our ordinary notions of cause and effect can give no account whatever. For every one of the individuals of which a species is made up, he will admit the adequacy of the ordinary process of generation; but for the species as a whole, this process seems to him inadequate, and he flies at once to that refuge of inconsequent and timid minds—*miracle!*

This is really just what Prof. Agassiz's theory of the origin of specific forms amounts to, and this is the reason why, in spite of grave heresy on minor points, he is now regarded by the evangelical Church as one of its chief champions. Instead of the natural process of generation—which is the only process by which we have ever known organic beings to be produced—he would fain set up some unknown mysterious process, the nature of which he is careful not to define, but for which he endeavors to persuade us that we have a fair equivalent in sonorous phrases concerning "creative will," "free action of an intelligent mind," and so on. In thus postponing considerations of pure science to considerations of "natural theology," I have no doubt Prof. Agassiz is actuated by a praiseworthy desire to do something for the glory of that Power of which the phenomenal universe is the perpetual but ever-changing manifestation. But how futile is such an attempt as this! How contrary to common-sense it is to say that a species is produced, *not* by the action of blind natural forces, *but* by an intelligent will! For, although this most prominent of all facts seems to be oftenest overlooked by theologians and others whom it most especially concerns, we are all the time, day by day and year by year, in each and every event of our lives, having experience of the workings of that Divine Power which, whether we attribute to it "intelligent will" or not, is unquestionably the one active agent in all the dynamic phenomena of Nature. Little as we know of the intrinsic nature of this Omnipresent Power, which, in our poor human talk, we call God, we do at least know, by daily and hourly experience, what is the character of its working. The whole experience of our lives teaches us that this Power works after a method which, in our scholastic expression, we call the method of cause and effect, or the method of natural law. Traditions of a barbarous and uncultivated age, in which mere grotesque associations of thoughts were mistaken for facts, have told us that this Power has, at various times in the past, worked in a different way—causing effects to appear without cognizable antecedents, even as Aladdin's palace rose in all its wondrous magnificence, without sound of carpenter's hammer or mason's chisel, in a single night. But about such modes of divine action we know nothing whatever from experience; and the awakening of literary criticism, in modern times, has taught us to distrust all such accounts of divine action which conflict with the lessons we learn from what is ever going on round about us. So far as we know aught concerning the works of God, which are being performed in us, through us, and around us, during every moment of that conscious intelligence which enables us to bear witness to them, we know they are works from which the essential relation of a given effect to its adequate cause is never absent. And for this reason, if we view the matter in pure accordance with experience, we are led to maintain that the antagonism or contrariety which seems to exist in Prof. Agassiz's mind between the action of God and the action of natural forces is nothing but a figment of that ancestral imagination from which the lessons which shaped Prof. Agassiz's ways of thinking were derived. So far as experience can tell us any thing, it tells us that divine action *is* the action of natural forces; for, if we refuse to accept this conclusion, what have we to do but retreat to the confession that we have no experience of divine action whatever, and that the works of God have been made manifest only to those who lived in that unknown time when Aladdin's palaces were built, and when species were created, in a single night, without the intervention of any natural process?

Trusting, then, in this universal teaching of experience, let us for a moment face fairly the problem which the existence of men upon the earth presents to us. Here is actually existing a group of organisms, which we call the human race. Either it has existed eternally, or some combination of circumstances has determined its coming into existence. The first alternative is maintained by no one, and our astronomical knowledge of the past career of our planet is sufficient decisively to exclude it. There is no doubt that at some time in the past the human race did not exist, and that its gradual or sudden coming into existence was determined by some combination of circumstances. Now, when Prof. Agassiz asks us to see, in this origination of mankind, the working of a Divine Power, we acquiesce in all reverence. But when he asks us to see in this origination of mankind the working of a Divine Power, *instead of* the working of natural causes, we do not acquiesce, because, so far as experience has taught us any thing, it has taught us that Divine Power never works except by the way of natural causation. Experience tells us that God causes Aladdin's palaces to come into existence gradually, through the coöperation of countless minute antecedents. And it tells us, most emphatically, that such structures do not come into existence without an adequate array of antecedents, no matter what the Arabian Nights may tell us to the contrary.

Now, when Prof. Agassiz asks us to believe that species have come into existence by means of a special creative fiat, and not through the operation of what are called natural causes, we reply that his request is mere inanity and nonsense. We have no reason to suppose that any creature like a man, or any other vertebrate, or articulate, or mollusk, ever came into existence by any other process than the familar process of physical generation. To ask us to believe in any other process is to ask us to abandon the experience which we have for the chimeras which we had best not seek to acquire. But Prof. Agassiz does not even suggest any other process for our acceptance. He simply retreats upon his empty phrases, "creative will," the "free workings of an intelligent mind," and so on. Now, in his second course of lectures, I hope he will proceed to tell us, not necessarily how "creative will" actually operated in bringing forth a new species, but how it *may* conceivably have operated, save through the process of physical generation, which we know. In his "Essay on Classification," I remember a passage in which he rightly rejects the notion that any species has arisen from a single pair of parents, and propounds the formula: "Pines have originated in forests, heaths in heather, grasses in prairies, bees in hives, herrings in shoals, buffaloes in herds, men in nations." Now, when Prof. Agassiz asserts that men originated in nations, by some other process than that of physical generation, what does he mean? Does he mean that men dropped down from the sky? Does he mean that the untold millions of organic particles which make up a man all rushed together from the four quarters of the compass, and proceeded, spontaneously or by virtue of some divine sorcery, to aggregate themselves into the infinitely complex organs and tissues of the human body, with all their wondrous and well-defined aptitudes? It is time that this question should be faced, by Prof. Agassiz and those who agree with him, without further shirking. Instead of grandiloquent phrases about the "free action of an intelligent mind," let us have something like a candid suggestion of some process, other than that of physical generation, by which a creature like man can even be imagined to have come into existence. When the time comes for answering this question, we shall find that even Prof. Agassiz is utterly dumb and helpless. The sonorous phrase "special creation," in which he has so long taken refuge, is nothing but a synthesis of vocal sounds which covers and, to some minds, conceals a thoroughly idiotic absence of sense or significance. To say that "Abracadabra is not a genial corkscrew," is to make a statement quite as full of meaning as the statement that species have originated by "special creation."

The purely theological (or theologico-metaphysical and at all events unscientific) character of Prof. Agassiz's objections to the development theory is sufficiently shown by the fact that, in the foregoing paragraphs, I have considered whatever of any account there is in his lectures which can be regarded as an objection. *Arguments* against the development theory such objections cannot be called: they are, at their very best, nothing but *expressions of fear and dislike.* The only remark which I have been able to find, worthy of being dignified as an argument, is the following: "We see that fishes are lowest, that reptiles are higher, that birds have a superior organization to both, and that mammals, with man at their head, are highest. The phases of development which a quadruped undergoes, in his embryonic growth, recall this gradation. He has a fish-like, a reptile-like stage before he shows unmistakable mammal-like features. We do not on this account suppose a quadruped grows out of a fish in our time, for this simple reason, that we live among quadrupeds and fishes, and we know that no such thing takes place. But resemblances of the same kind, separated by geological ages, allow play for the imagination, and for inference unchecked by observation."

I do not believe that Prof. Agassiz's worst enemy—if he ever had an enemy—could have been so hard-hearted as to wish for him the direful catastrophe into which this wonderful piece of argument has plunged him irretrievably. For the question must at once suggest itself to every reader at all familiar with the subject, If Prof. Agassiz supposes that the development theory, as held nowadays, implies that a quadruped was ever the direct issue of a fish, of what possible value can his opinion be as regards the development theory in any way?

If I may speak frankly, as I have indeed been doing from the outset, I will say that, as regards the Darwinian theory, Prof. Agassiz seems to me to be hopelessly behind the age. I have never yet come across the first indication that he knows what the Darwinian theory is. Against the development theory, as it was taught him by the discussions of forty years ago, he is fond of uttering, I will not say arguments, but expressions of dislike. With the modern development theory, with the circumstances of variation, heredity, and natural selection, he never, in any of his writings, betrays the slightest acquaintance. Against a mere man of straw of his own devising, he industriously hurls anathemas of a quasi-theological character. But any thing like a scientific examination of the character and limits of the agency of natural selection in modifying the appearance and structure of a species, any thing like such an examination as is to be found in the interesting work of Mr. St. George Mivart, he has never yet brought forth.

Now, when Prof. Agassiz fairly comes to an issue, if he ever does, and undertakes to refute the Darwinian theory, these are some of the questions which he will have to answer: 1. If all organisms are not associated through the bonds of common descent, why is it that the facts of classification are just such as they would have been had they been due to such a common descent? 2. Why does a mammal always begin to develop as if it were going to become a fish, and then, changing its tactics, proceed as if it were going to become a reptile or bird, and only after great delay and circumlocution take the direct road toward mammality? In answer to this, we do not care to be told that a mammal never was the son of a fish, because we know that already; nor do we care to hear any more about the "free manifestations of an intelligent mind," because we have had quite enough of metaphysical phrases which do not contain a description of some actual or imaginable process. We want to know how this state of things can be scientifically interpreted save on the hypothesis of a common ultimate origin for mammals, birds, reptiles, and fishes. 3. What is the meaning of such facts as the homologies which exist between corresponding parts of organisms constructed on the same type? Why does the black salamander retain fully-developed gills which he never uses, and what is the significance of rudimentary and aborted organs in general? Again I say, we do not want to hear about "uniformity of design" and "reminiscences of a plan," and so on, but we wish to know how this state of things was physically brought about, save by community of descent. 4. Why is it that the facts of geological succession and geographical distribution so clearly indicate community of descent, unless there has actually been community of descent? Why have marsupials in Australia followed after other marsupials, and edentata in South America followed after other edentata, with such remarkable regularity, unless the bond which unites present with past ages be the well-known, the only known, and the only imaginable bond of physical generation? Why are the fauna and flora of each geologic epoch in general intermediate in character between the flora and fauna of the epochs immediately preceding and succeeding? And, 5. What are we to do with the great fact of *extinction* if we reject Mr. Darwin's explanations? When a race is extinguished, is it because of a universal deluge, or because of the "free manifestations of an intelligent mind?" For surely Prof. Agassiz will not attribute such a solemn result to such ignoble causes as insufficiency of food or any other of the thousand causes, "blindly mechanical," which conspire to make a species succumb in the struggle for life.

And here the phrase, "struggle for life," reminds me of yet another difficult task which Prof. Agassiz will have before him when he comes to undertake the refutation of Darwinism in earnest. He will have to explain away the enormous multitude of facts which show that there is a struggle for life in which the fittest survive; or he will at any rate have to show in what imaginable way an organic type can remain constant in all its features through countless ages under the influence of such circumstances, unless by taking into the account the Darwinian interpretation of persistent types offered by Prof. Huxley.

But I will desist from further enumeration of the difficulties which surround this task which Prof. Agassiz has not undertaken, and is not likely ever to undertake. For the direct grappling with that complicated array of theorems which the genius of such men as Darwin and Spencer and their companions has established on a firm basis of observation and deduction, Prof. Agassiz seems in these lectures hardly better qualified than a child is qualified for improving the methods of the integral calculus. These questions have begun to occupy earnest thinkers since the period when his mind acquired that rigidity which prevents the revising of one's opinions. The marvellous flexibility of thought with which Sir Charles Lyell so gracefully abandoned his antiquated position, Prof. Agassiz is never likely to show. This is largely because Lyell has always been a thinker of purely scientific habit, while Agassiz has long been accustomed to making profoundly dark metaphysical phrases do the work which properly belongs to observation and deduction. But, however we may best account for these idiosyncrasies, it remains most probable among those facts which are still future, that Prof. Agassiz will never advance any more crushing refutation of the Darwinian theory than the simple expression of his personal dislike for "mechanical agencies," and his belief in the "free manifestations of an intelligent mind." Were he only to be left to himself, such expressions of personal preference could not mar the pleasure with which we often read his exposition of purely scientific truths. But when he is brought before the public as the destroyer of a theory, the elements of which he has never yet given any sign of having mastered, he is placed in a false position, which would be ludicrous could he be supposed to have sought it, and which is, at all events, unworthy of his eminent fame.

THE PRIMARY CONCEPTS OF MODERN PHYSICAL SCIENCE.

ERRATUM.

Page 710, line 32, for "impenetrability," read "compenetrability."

"Natural science," says Du Bois-Reymond,[1] "is a reduction of the changes in the material world to motions of atoms caused by central forces independent of time, or a resolution of the phenomena of Nature into atomic mechanics. . . . The resolution of all changes in the material world into motions of atoms caused by their constant central forces would be the completion of natural science."

Obviously, the proposition thus enounced assigns to physical sci-

[1] "Ueber die Grenzen des Naturerkennens. Ein Vortrag in der zweiten öffentlichen Sitzung der 45. Versammlung deutscher Naturforscher und Aerzte zu Leipzig am 14. August 1872, gehalten von Emil Du Bois-Reymond." Leipzig, Veit & Comp., 1872.

ence limits so narrow that all attempts to bring the characteristic phenomena of organic life (not to speak of mental action) within them are utterly hopeless. Nevertheless, it is asserted that organic phenomena are the product of ordinary physical forces alone, and that the assumption of vital agencies, as distinct from the forces of inorganic Nature, is wholly inadmissible. In view of this, it seems strange that the validity of the proposition above referred to has never, so far as I know, been questioned, except in the interest of some metaphysical or theological system. It is my purpose in the following essays to offer a few suggestions in this behalf, in order to ascertain, if possible, whether the prevailing primary notions of physical science can stand, or are in need of revision.

One of the prime postulates of the mechanical theory is the atomic constitution of matter. A discussion of this theory, therefore, at once leads to an examination of the grounds upon which the assumption of atoms, as the ultimate constituents of the physical world, rests.

The doctrine that an exhaustive analysis of a material body into its real elements, if it could be practically effected, would yield an aggregate of indivisible and indestructible particles, is almost coeval with human speculation, and has held its ground more persistently than any other tenet of science or philosophy. It is true that the atomic theory, since its first promulgation by the early Greek philosophers, and its elaborate statement by Lucretius, has been modified and refined. There is probably no one, at this day, who invests the atoms with hooks and loops, or (Lucretius, *De Rerum Natura*, ii., 398, *et seq.*) accounts for the bitter taste of wormwood by the raggedness, and for the sweetness of honey by the smooth roundness of the constituent atoms. But the "atom" of modern science is still of determinate weight, if not of determinate figure, and stands for something more than an abstract unit, even in the view of those who, like Boscovich, Faraday, Ampère, or Fechner, profess to regard it as a mere centre of force. And there is no difficulty in stating the atomic doctrine in terms applicable alike to all the acceptations in which it is now held by scientific men. Whatever diversity of opinion may prevail as to the form, size, etc., of the atoms, all who advance the atomic hypothesis, in any of its varieties, as a physical theory, agree in three propositions, which may be stated as follows:

1. *Atoms are absolutely simple, unchangeable, indestructible; they are physically, if not mathematically, indivisible.*

2. *Matter consists of discrete parts, the constituent atoms being separated by void interstitial spaces. In contrast to the continuity of space stands the discontinuity of matter. The expansion of a body is simply an increase, its contraction a lessening of the spatial intervals between the atoms.*

3. *The atoms composing the different chemical elements are of de-*

terminate specific weights, corresponding to their equivalents of combination.[1]

Confessedly the atomic theory is but an hypothesis. This in itself is not decisive against its value; all physical theories properly so called are hypotheses whose eventual recognition as truths depends upon their consistency with themselves, upon their agreement with the canons of logic, upon their congruence with the facts which they serve to connect and explain, upon their conformity with the ascertained order of Nature, upon the extent to which they approve themselves as reliable anticipations or previsions of facts verified by subsequent observation or experiment, and finally upon their simplicity, or rather their reducing power. The merits of the atomic theory, too, are to be determined by seeing whether or not it satisfactorily and simply accounts for the phenomena as the explanation of which it is propounded, and whether or not it is in harmony with itself and with the known laws of Reason and of Nature.

For what facts, then, is the atomic hypothesis meant to account, and to what degree is the account it offers satisfactory?

It is claimed that the first of the three propositions above enumerated (the proposition which asserts the persistent integrity of atoms, or their unchangeability both in weight and volume) accounts for the indestructibility and impenetrability of matter; that the second of these propositions (relating to the discontinuity of matter) is an indispensable postulate for the explanation of certain physical phenomena, such as the dispersion and polarization of light; and that the third proposition (according to which the atoms composing the chemical elements are of determinate specific gravities) is the necessary general expression of the laws of definite constitution, equivalent proportion, and multiple combination, in chemistry.

In discussing these claims, it is important, first, to verify the facts and to reduce the statements of these facts to exact expression, and then to see how far they are fused by the theory:

1. The indestructibility of matter is an unquestionable truth. But in what sense, and upon what grounds, is this indestructibility predicated of matter? The unanimous answer of the atomists is: Experience teaches that all the changes to which matter is subject are but variations of form, and that amid these variations there is an unvarying constant—the mass or quantity of matter. The constancy of the mass is attested by the balance, which shows that neither fusion nor sublimation, neither generation nor corruption, can add to or detract from the weight of a body subjected to experiment. When a pound of carbon is burned, the balance demonstrates the continuing exist-

[1] To avoid confusion, I purposely ignore the distinction between *molecules* as the ultimate products of the physical division of matter, and *atoms* as the ultimate products of its chemical decomposition, preferring to use the word *atoms* in the sense of the least particles into which bodies are divisible or reducible by any means.

ence of this pound in the carbonic acid, which is the product of combustion, and from which the original weight of carbon may be recovered. The quantity of matter is measured by its weight, and this weight is unchangeable.

Such is the fact, familiar to every one, and its interpretation, equally familiar. To test the correctness of this interpretation, we may be permitted slightly to vary the method of verifying it. Instead of burning the pound of carbon, let us simply carry it to the summit of a mountain, or remove it to a lower latitude; is its weight still the same? Relatively it is; it will still balance the original counterpoise. But the absolute weight is no longer the same. This appears at once, if we give to the balance another form, taking a pendulum instead of a pair of scales. The pendulum on the mountain or near the equator vibrates more slowly than at the foot of the mountain or near the pole, for the reason that it has become specifically lighter by being farther removed from the centre of the earth's attraction, in conformity to the law that the attractions of bodies vary inversely as the squares of their distances.

It is thus evident that the constancy, upon the observation of which the assertion of the indestructibility of matter is based, is simply the constancy of a relation, and that the ordinary statement of the fact is crude and inadequate. Indeed, while it is true that the weight of a body is a measure of its mass, this is but a single case of the more general fact that the masses of bodies are inversely as the velocities imparted to them by the action of the same force, or, more generally still, inversely as the accelerations produced in them by the same force. In the case of gravity, the forces of attraction are directly proportional to the masses, so that the action of the forces (*weight*) is the simplest measure of the relation between any two masses as such; but, in any inquiry relating to the validity of the atomic theory, it is necessary to bear in mind that this weight is not the equivalent, or rather presentation, of an absolute substantive entity in one of the bodies (the body weighed), but the mere expression of a relation between two bodies mutually attracting each other. And it is further necessary to remember that this weight may be indefinitely reduced, without any diminution in the mass of the body weighed, by a mere change of its position in reference to the body between which and the body weighed the relation subsists.[1]

[1] The thoughtlessness with which it is assumed by some of the most eminent mathematicians and physicists that matter is composed of particles which have an absolute primordial weight persisting in all positions, and under all circumstances, is one of the most remarkable facts in the history of science. To cite but one instance: Prof. Rettenbacher, one of the ablest analysts of his day, in his "Dynamidensystem" (Mannheim, Bassermann, 1857), p. 14, says, "The absolute weight of atoms is unknown"—his meaning being, as is evident from the context and from the whole tenor of his discussion, that our ignorance of this absolute weight is due solely to the practical impossibility of insulating an atom, and of contriving instruments delicate enough to weigh it.

Masses find their true and only measure in the action of forces, and the quantitative persistence of the effect of this action is the simple and accurate expression of the fact which is ordinarily described as the indestructibility of matter. It is obvious that this persistence is in no sense explained or accounted for by the atomic hypothesis. It may be that such persistence is an attribute of the minute, insensible particles which are supposed to constitute matter, as well as of sensible masses; but, surely, the hypothetical recurrence of a fact in the atom is no explanation of the actual occurrence of the same fact in the conglomerate mass. Whatever mystery is involved in the phenomenon is as great in the case of the atom as in that of a solar or planetary sphere. Breaking a magnet into fragments, and showing that each fragment is endowed with the magnetic polarity of the integer magnet, is no explanation of the phenomenon of magnetism. A phenomenon is not explained by being dwarfed. A fact is not transformed into a theory by being looked at through an inverted telescope. The hypothesis of ultimate indestructible atoms is not a necessary implication of the persistence of weight, and can at best account for the indestructibility of matter if it can be shown that there is an absolute limit to the compressibility of matter—in other words, that there is an absolutely least volume for every determinate mass. This brings us to the consideration of that general property of matter which probably, in the minds of most men, most urgently requires the assumption of atoms—its impenetrability.

"Two bodies cannot occupy the same space"—such is the familiar statement of the fact in question. Like the indestructibility of matter, it is claimed to be a datum of experience. "*Corpora omnia impenetrabilia esse*," says Sir Isaac Newton (*Phil. Nat. Princ. Math.*, lib. iii., reg. 3), "*non ratione sed sensu colligimus.*" Let us see in what sense and to what extent this claim is legitimate.

The proposition, according to which a space occupied by one body cannot be occupied by another, implies the assumption that space is an absolute, self-measuring entity—an assumption which I may have occasion to examine hereafter—and the further assumption that there is a least space which a given body will absolutely fill so as to exclude any other body. A verification of this proposition by experience, therefore, must amount to proof that there is an absolute limit to the compressibility of all matter whatsoever. Now, does experience authorize us to assign such a limit? Assuredly not. It is true that in the case of solids and liquids there are practical limits beyond which compression by the mechanical means at our command is impossible; but even here we are met by the fact that the volumes of fluids, which effectually resist all efforts at further reduction by external pressure, are readily reduced by mere mixture. Thus, sulphuric acid and water at ordinary temperatures do not sensibly yield to pressure; but, when they are mixed, the resulting volume is materially less than the aggregate volumes of the liquids mixed. But, waiving this, as well as the phenomena which emerge in the processes of solution and chemical action, it must be said that experience does not in any manner vouch for the impenetrability of matter as such in all its states of aggregation. When gases are subjected to pressure, the result is simply an increase of the expansive force in proportion to the pressure exerted, according to the law of Boyle and Mariotte (the modifications of and apparent exceptions to which, as exhibited in the experimental results obtained by Regnault and others, need not here be stated, because they do not affect the argument). A definite experimental limit is reached in the case of those gases only in which the pressure produces liquefaction or solidification. The most significant phenomenon, however, which experience contributes to the testimony on this subject is the diffusion of gases. Whenever two or more gases which do not act upon each other chemically are introduced into a given space, each gas diffuses itself in this space as though it were alone present there; or, as Dalton, the reputed father of the modern atomic theory, expresses it, "Gases are mutually passive, and pass into each other as into vacua."

Whatever reality may correspond to the notion of the impenetrability of matter, this impenetrability is not, in the sense of the atomists, a datum of experience.

Upon the whole, it would seem that the validity of the first proposition of the atomic theory is not sustained by the facts. Even if the assumed unchangeability of the supposed ultimate constituent particles of matter presented itself, upon its own showing, as more than a bare reproduction of an observed fact in the form of an hypothesis, and could be dignified with the name of a generalization or of a theory, it would still be obnoxious to the criticism that it is a generalization from facts crudely observed and imperfectly apprehended.

In this connection it may be observed that the atomic theory has become next to valueless as an explanation of the impenetrability of matter, since it has been pressed into the service of the undulatory theory of light, heat, etc., and assumed the form in which it is now held by the majority of physicists, as we shall presently see. According to this form of the theory, the atoms are either mere points, wholly without extension, or their dimensions are infinitely small as compared with the distances between them, whatever be the state of aggregation of the substances into which they enter. In this view the resistance which a body, i. e., a system of atoms, offers to the intrusion of another body is due, not to the rigidity or unchangeability of volume of the individual atoms, but to the relation between the attractive and repulsive forces with which they are supposed to be endowed. There are physicists holding this view who are of opinion that the atomic constitution of matter is consistent with its impenetrability—among them M. Cauchy, who, in his *Sept Leçons de Phy-*

sique Générale (ed. Moigno, Paris, 1868, p. 38), after defining atoms as "material points without extension," uses this language: "Thus, this property of matter which we call impenetrability is explained, when we consider the atoms as material points exerting on each other attractions and repulsions which vary with the distances that separate them. . . . From this it follows that, if it pleased the author of Nature simply to modify the laws according to which the atoms attract or repel each other, we might instantly see the hardest bodies penetrate each other" (that we might see), "the smallest particles of matter occupy immense spaces, or the largest masses reduce themselves to the smallest volumes, the entire universe concentrating itself, as it were, in a single point."

2. The second fundamental proposition of the modern atomic theory avouches the essential discontinuity of matter. The advocates of the theory affirm that there is a series of physical phenomena which are inexplicable, unless we assume that the constituent particles of matter are separated by void interspaces. The most notable among these phenomena are the dispersion and polarization of light. The grounds upon which the assumption of a discrete molecular structure of matter is deemed indispensable for the explanation of these phenomena may be stated in a few words.

According to the undulatory theory, the dispersion of light, or its separation into spectral colors, by means of refraction, is a consequence of the unequal retardation experienced by the different waves, which produce the different colors, in their transmission through the refracting medium. This unequal retardation presupposes differences in the velocities with which the various-colored rays are transmitted through any medium whatever, and a dependence of these velocities upon the lengths of the waves. But, according to a well-established mechanical theorem, the velocities with which undulations are propagated through a continuous medium depend solely upon the elasticity of the medium as compared with its inertia, and are wholly independent of the length and form of the waves. The correctness of this theorem is attested by experience in the case of sound. Sounds of every pitch travel with the same velocity. If it were otherwise, music heard at a distance would evidently become chaotic; differences of velocity in the propagation of sound would entail a distortion of the rhythm, and, in many cases, a reversal of the order of succession. Now, differences of color are analogous to differences of pitch in sound, both reducing themselves to differences of wave-length. The lengths of the waves increase as we descend the scale of sounds from those of a higher to those of a lower pitch; and similarly, the length of a luminar undulation increases as we descend the spectral scale, from violet to red. It follows, then, that the rays of different color, like the sounds of different pitch, should be propagated with equal velocities, and be equally refracted; that, therefore, no dispersion of light should take place.

This theoretical impossibility of dispersion has always been recognized as one of the most formidable difficulties of the undulatory theory. In order to obviate it, Cauchy, at the suggestion of his friend Coriolis, entered upon a series of analytical investigations, in which he succeeded in showing that the velocities with which the various colored rays are propagated may vary according to the wave-lengths, if it be assumed that the ethereal medium of propagation, instead of being continuous, consists of particles separated by sensible distances.

By means of a similar assumption, Fresnel has sought to remove the difficulties presented by the phenomena of polarization. In ordinary light, the different undulations are supposed to take place in different directions, all transverse to the course or line of propagation, while in polarized light the vibrations, though still transverse to the ray, are parallelized, so as to occur in the same plane. Soon after this hypothesis had been expanded into an elaborate theory of polarization, Poisson observed that, at any considerable distance from the source of the light, all transverse vibrations in a continuous elastic medium must become longitudinal. As in the case of dispersion, this objection was met by the hypothesis of the existence of "definite intervals" between the ethereal particles.

These are the considerations, succinctly stated, which theoretical physics are supposed to bring to the support of the atomic theory. In reference to the cogency of the argument founded upon them, it is to be said, generally, that evidence of the discrete molecular arrangement of matter is by no means proof of the alternation of unchangeable and indivisible atoms with absolute spatial voids. But it is to be feared that the argument in question is not only formally, but also materially, fallacious. It is very questionable whether the assumption of definite intervals between the particles of the luminiferous ether is competent to relieve the undulatory theory of light from its embarrassments. This subject, in one of its aspects, has been thoroughly discussed by E. B. Hunt, in an article on the dispersion of light (*Silliman's Journal*, vol. vii., 2d series, p. 364, *et seq.*), and the suggestions there made appear to me worthy of serious attention. They are briefly these:

M. Cauchy brings the phenomena of dispersion within the dominion of the undulatory theory, by deducing the differences in the velocities of the several chromatic rays from the differences in the corresponding wave-lengths by means of the hypothesis of definite intervals between the particles of the light-bearing medium. He takes it for granted, therefore, that these chromatic rays are propagated with different velocities. But is this the fact? Astronomy affords the means to answer this question.

We experience the sensation of white light, when all the chromatic rays of which it is composed strike the eye simultaneously. The light proceeding from a luminous body will appear colorless, even if the component rays move with unequal velocities, provided all the colored rays, which together make up white light, concur in their action on the retina at a given moment; in ordinary cases it is immaterial whether these rays have left the luminous body successively or together. But it is otherwise when a luminous body becomes visible suddenly, as in the case of the satellites of Jupiter, or Saturn, after their eclipses. At certain periods, more than 49 minutes are requisite for the transmission of light from Jupiter to the earth. Now, at the moment when one of Jupiter's satellites, which has been eclipsed by that planet, emerges from the shadow, the red rays, if their velocity were the greatest, would evidently reach the eye first, the orange next, and so on through the chromatic scale, until finally the complement of colors would be filled by the arrival of the violet ray, whose velocity is supposed to be the least. The satellite, immediately after its emersion, would appear red, and gradually, in proportion to the arrival of the other rays, pass into white. Conversely, at the beginning of the eclipse, the violet rays would continue to arrive after the red and other intervening rays, and the satellite, up to the moment of its total disappearance, will gradually shade into violet.

Unfortunately for Cauchy's hypothesis, the most careful observation of the eclipses in question has failed to reveal any such variations of color, either before immersion, or after emersion, the transition between light and darkness taking place instantaneously, and without chromatic gradations.

If it be said that these chromatic gradations escape our vision by reason of the inappreciability of the differences under discussion, astronomy points to other phenomena no less subversive of the doctrine of unequal velocities in the movements of the chromatic undulations. Fixed stars beyond the parallactic limit, whose light must travel more than three years before it reaches us, are subject to great periodical variations of splendor; and yet these variations are unaccompanied by variations of color. Again, the assumption of different velocities for the different chromatic rays is discountenanced by the theory of aberration. Aberration is due to the fact that, in all cases where the orbit of the planet, on which the observer is stationed, forms an angle with the direction of the luminar ray, a composition takes place between the motion of the light and the motion of the planet, so that the direction in which the light meets the eye is a resultant of the two component directions—the direction of the ray and that of the observer's motion. If the several rays of color moved with different velocities there would evidently be several resultants, and each star would appear as a colored spectrum longitudinally parallel to the direction of the earth's motion.

The alleged dependence of the velocity of the undulatory movements, which correspond to, or produce, the different colors, upon the length of the waves, is thus at variance with observed fact. The hypothesis of definite intervals is unavailable as a supplement to the undulatory theory; other methods will have to be resorted to in order to free this theory from its difficulties.[1]

3. The third proposition of the atomic hypothesis assigns to the atoms, which are said to compose the different chemical elements, determinate weights corresponding to their equivalents of combination, and is supposed to be necessary to account for the facts whose enumeration and theory constitute the science of chemistry. The proper verification of these facts is of great difficulty, because they have generally been observed through the lenses of the atomic theory, and stated in its doctrinal terms. Thus the differentiation and integration of bodies are invariably described as decomposition and composition; the equivalents of combination are designated as atomic weights or volumes, and the greater part of chemical nomenclature is a systematic reproduction of the assumptions of atomism. Nearly all the facts to be verified are in need of preparatory enucleation from the envelops of this theory.

The phenomena usually described as chemical composition and decomposition present themselves to observation thus: A number of heterogeneous bodies concur in definite proportions of weight or volume; they interact; they disappear, and give rise to a new body possessing properties which are neither the sum nor the mean of the properties of the bodies concurring and interacting (excepting the weight which is the aggregate of the weights of the interacting bodies), and this conversion of several bodies into one is accompanied, in most cases, by changes of volume, and in all cases by the evolution or involution of heat, or light, or of both. Conversely, a single homogeneous body gives rise to heterogeneous bodies, between which and the body out of which they originate the persistence of weight is the only relation of identity.

For the sake of convenience, these phenomena may be distributed into three classes, of which the first embraces the persistence of weight and the combination in definite proportions; the second, the changes of volume and the evolution of light and heat; and the third, the emergence of a wholly new complement of chemical properties.

Obviously, the atomic hypothesis is in no sense an explanation of the phenomena of the second class. It is clearly and confessedly in-

[1] Cauchy's theory of dispersion is subject to another difficulty, of which no note is taken by Hunt: it does not account for the different refracting powers of different substances. Indeed, according to Cauchy's formulæ (whose terms are expressive simply of the distances between the ethereal particles and their hypothetical forces of attraction and repulsion), the refracting powers of all substances whatever must be the same, unless each substance is provided with a peculiar ether of its own. If this be the case, the assemblage of atoms in a given body is certainly a very motley affair, especially if it be true, as W. A. Norton and several other physicists assert, that there is an electric ether distinct from the luminiferous ether. Rettenbacher ("Dynamidensystem," p. 130, *et seq.*) attempts to overcome the difficulty by the hypothesis of mutual action between the corpuscular and ethereal atoms.

competent to account for changes of volume or of temperature. And, with the phenomena of the third class, it is apparently incompatible. For, in the light of the atomic hypothesis, chemical compositions and decompositions are in their nature nothing more than aggregations and segregations of masses whose integrity remains inviolate. But the radical change of chemical properties, which is the result of all true chemical action, and serves to distinguish it from mere mechanical mixture or separation, evinces a thorough destruction of that integrity. It may be that the appearance of this incompatibility can be obliterated by the device of ancillary hypotheses; but that leads to an abandonment of the simplicity of the atomic hypothesis itself, and thus to a surrender of its claims to merit as a theory.

At best, then, the hypothesis of atoms of definite and different weights can be offered as an explanation of the phenomena of the first class. Does it explain them in the sense of generalizing them, of reducing many facts to one? Not at all; it accounts for them, as it professed to account for the indestructibility and impenetrability of matter, by simply iterating the observed fact in the form of an hypothesis. It is another case (to borrow a scholastic phrase) of illustrating *idem per idem.* It says: The large masses combine in definitely-proportionate weights because the small masses, the atoms of which they are multiples, are of definitely-proportionate weight. It pulverizes the fact, and claims thereby to have sublimated it into a theory.

Upon closer examination, moreover, the assumption of atoms of different specific gravities proves to be, not only futile, but absurd. Its manifest theoretical ineptitude is found to mask the most fatal inconsistencies. According to the mechanical conception which underlies the whole atomic hypothesis, differences of weight are differences of density; and differences of density are differences of distance between the particles contained in a given space. Now, in the atom there is no multiplicity of particles, and no void space; hence differences of density or weight are impossible in the case of atoms.

It is to be observed that the attribution of different weights to different atoms is an indispensable feature of the atomic theory in chemistry, especially in view of the combination of gases in simple ratios of volume, so as to give rise to gaseous products bearing a simple ratio to the volumes of its constituents, and in view of the law of Ampère and Clausius, according to which all gases, of whatever nature or weight, contain equal numbers of molecules in equal volumes.

The inadequacy of the atomic hypothesis as a theory of chemical changes has been repeatedly pointed out by men of the highest scientific authority, such as Grove (*Correlation of Physical Forces*, in Youmans's "Correlation and Conservation of Forces," p. 164, *et seq.*), and is becoming more apparent from day to day. I shall have occasion to inquire, hereafter, what promise there is, in the present state of chemical science, of a true generalization of the phenomena of combination in definite proportions, both of weight and volume, which is independent of the atomic doctrine, and will serve to connect a number of concomitant facts for which this doctrine is utterly incompetent to account.

It is not infrequently asserted by the advocates of the atomic theory that there is a number of other phenomena, in addition to those of combination in definite proportions, which are strongly indicative of the truth of the atomic theory. Among these phenomena are isomerism, polymerism, and allotropy. But it is very doubtful whether this theory is countenanced by the phenomena in question. The existence of different allotropic states, in an elementary body said to consist of but one kind of atoms, is explicable by the atomic hypothesis in no other way than by deducing these different states from diversities in the grouping of the different atoms. But this explanation applies to solids only, and fails in the cases of liquids and gases. The same remark applies to isomerism and polymerism.

From the foregoing considerations, I take it to be clear that the atomic hypothesis mistakes many of the facts which it seeks to explain; that it accounts imperfectly or not at all for a number of other facts which are correctly apprehended; and that there are cases in which it appears to be in irreconcilable conflict with the data of experience. As a physical theory, it is barren and useless, inasmuch as it lacks the first requisite of a true theory—that of being a generalization, a reduction of several facts to one; it is essentially one of those spurious figments of the brain, based upon an ever-increasing *multiplicatio entium praeter necessitatem*, which are characteristic of the prescientific epochs of human intelligence, and against which the whole spirit of modern science is an emphatic protest. Moreover, in its logical and psychological aspect, as we shall hereafter see more clearly, it is the clumsiest attempt ever made to transcend the sphere of relations in which all objective reality, as well as all thought, has its being, and to grasp the absolute "*ens per sese, finitum, reale, totum.*"

I do not speak here of a number of other difficulties which emerge upon a minute examination of the atomic hypothesis in its two principal varieties, the atoms being regarded by some physicists as extended and figured masses, and by others as mere centres of force. In the former case the assumption of physical indivisibility becomes gratuitous, and that of mathematical indivisibility absurd; while in the latter case the whole basis of the relation between force and mass, or rather force and inertia, without which the conception of either term of the relation is impossible, is destroyed. Some of these difficulties are frankly admitted by leading men of science—for instance, by Du Bois-Reymond, in the lecture above cited. Nevertheless, it is asserted that the atomic, or at least molecular, constitution of matter is the only form of material existence which can be realized in thought. In what sense, and to what extent, this assertion is well founded, will be my next subject of examination.

FINDING THE WAY AT SEA.

By R. A. PROCTOR.

THE wreck of the Atlantic, followed closely by that of the City of Washington nearly on the same spot, has led many to inquire into the circumstances on which depends a captain's knowledge of the position of his ship. In each case, though not in the same way, the ship was supposed to be far from land, when in reality quite close to it. In each case, in fact, the ship had oversailed her reckoning. A slight exaggeration of what travellers so much desire—a rapid passage—proved the destruction of the ship, and in one case occasioned a fearful loss of life. And, although such events are fortunately infrequent in Atlantic voyages, yet the bare possibility that, besides ordinary sea-risks, a ship is exposed to danger from simply losing her way, suggests unpleasant apprehensions as to the general reliability of the methods in use for determining where a ship is, and her progress from day to day.

I propose to give a brief sketch of the methods in use for finding the way at sea, in order that the general principles on which safety depends may be recognized by the general reader.

It is known, of course, to every one, that a ship's course and rate of sailing are carefully noted throughout her voyage. Every change of her course is taken account of, as well as every change in her rate of advance, whether under sail or steam, or both combined. If all this could be quite accurately managed, the position of the ship at any hour could be known, because it would be easy to mark down on a chart the successive stages of her journey, from the moment when she left port. But a variety of circumstances renders this impossible.

To begin with: the *exact* course of a ship cannot be known, because there is only the ship's compass to determine her course by, and a ship's compass is not an instrument affording perfectly exact indications. Let any one on a sea-voyage observe the compass for a short time, being careful not to break the good old rule which forbids speech to the "man at the wheel," and he will presently become aware of the fact that the ship is not kept rigidly to one course, even for a short time. The steersman keeps her as near as he can to a particular course, but she is continually deviating, now a little on one side, now a little on the other, of the intended direction; and even the general accuracy with which that course is followed is a matter of estimation, and depends on the skill of the individual steersman. Looking at the compass-card, in steady weather, a course may seem very closely followed; perhaps the needle's end may not be a hundredth part of an inch (on the average) from the position it should have. But a hundredth part of an inch on the circumference of the compass-card would correspond to a considerable deviation in the course of a run of twenty or thirty knots; and there is nothing to prevent the errors so arising from accumulating in a long journey until a ship might be thirty or forty miles from her estimated place. To this may be added the circumstance that the direction of the needle is different in different parts of the earth. In some places it points to the east of the north, in others to the west. And, although the actual "variation of the compass," as this peculiarity is called, is known in a general way for all parts of the earth, yet such knowledge has no claim to actual exactness. There is also an important danger, as recent instances have shown, in the possible change of the position of the ship's compass, on account of iron in her cargo.

But a far more important cause of error, in determinations merely depending on the log-book, is that arising from uncertainty as to the ship's rate of progress. The log-line gives only a rough idea of the ship's rate at the time when the log is cast;[1] and, of course, a ship's rate does not remain constant, even when she is under steam alone. Then, again, currents carry the ship along sometimes with considerable rapidity; and the log-line affords no indication of their action: while no reliance can be placed on the estimated rates, even of known currents. Thus the distance made on any course may differ considerably from the estimated distance; and, when several days' sailing are dealt with, an error of large amount may readily accumulate.

For these and other reasons, a ship's captain places little reliance on what is called "the day's work"—that is, the change in the ship's position from noon to noon as estimated from the compass-courses entered in the log-book, and the distances supposed to be run on these courses. It is absolutely essential that such estimates should be carefully made, because, under favorable conditions of weather, there may be no other means of guessing at the ship's position. But the only really reliable way of determining a ship's place is by astronomical observations. It is on this account that the almanac published by the Admiralty, in which the position and apparent motions of the celestial bodies are indicated, four or five years in advance, is called, *par excel-*

[1] The log is a flat piece of wood of quadrantal shape, so loaded at the rim as to float with the point (that is, the centre of the quadrant) uppermost. To this a line about 300 yards long is fastened. The log is thrown overboard, and comes almost immediately to rest on the surface of the sea, the line being suffered to run freely out. By marks on the log-line divided into equal spaces, called *knots*, of known length, and by observing how many of these run out, while the sand in a half-minute hour-glass is running, the ship's rate of motion is roughly inferred. The whole process is necessarily rough, since the line cannot even be straightened.

lence, the *Nautical Almanac*. The astronomer, in his fixed observatory, finds this almanac essential to the prosecution of his observations; the student of theoretical astronomy has continual occasion to refer to it; but, to the sea-captain, the *Nautical Almanac* has a far more important use. The lives of sailors and passengers are dependent upon its accuracy. It is, again, chiefly for the sailor that our great nautical observatories have been erected, and that our astronomer-royal and his officers are engaged. What other work they may do is subsidiary, and, as it were, incidental. Their chief work is to time this great clock, our earth, and so to trace the motions of those celestial indices, which afford our fundamental time-measures, as to insure as far as possible the safety of our navy, royal and mercantile.[1]

Let us see how this is brought about, not, indeed, by inquiring into the processes by which, at the Greenwich Observatory, the elements of safety are obtained, but by considering the method by which a seaman makes use of these elements.

In the measures heretofore considered, the captain of a ship in reality relies on terrestrial measurements. He reasons that, being on such and such a day in a given place, and having in the interval sailed so many miles in such and such directions, he must at the time being be in such and such a place. This is called "navigation." In the processes next to be considered, which constitute a part of the science of nautical astronomy, the seaman trusts to celestial observations independently of all terrestrial measurements.

The points to be determined by the voyager are his latitude and longitude. The latitude is the distance north or south of the equator, and is measured always from the equator in degrees, the distance from equator to pole being divided into ninety equal parts, each of which is a degree.[2] The longitude is the distance east or west of Greenwich (in English usage, but other nations employ a different starting-point for measuring longitudes from). Longitude is not measured in miles, but in degrees. The way of measuring is not very

[1] This consideration has been altogether lost sight of in certain recent propositions for extending government aid to astronomical inquiries of another sort. It may be a most desirable thing that government should find means for inquiring into the physical condition of sun and moon, planets and comets, stars and all the various orders of star-clusters. But, if such matters are to be studied at government expense, it should be understood that the inquiry is undertaken with the sole purpose of advancing our knowledge of these interesting subjects, and should not be brought into comparison with the utilitarian labors for which our Royal Observatory was founded.

[2] Throughout this explanation all minuter details are neglected. In reality, in consequence of the flattening of the earth's globe, the degrees of latitude are not equal, being larger the farther we go from the equator. Moreover, strictly speaking, it is incorrect to speak of distances being divided into degrees, or to say that a degree of latitude or longitude contains so many miles; yet it is so exceedingly inconvenient to employ any other way of speaking in popular description, that I trust any astronomers or mathematicians who may read this article will forgive the solecism.

readily explained without a globe or diagrams, but may be thus indicated: Suppose a circle to run completely round the earth, through Greenwich and both the poles; now, if this circle be supposed free to turn upon the polar axis, or on the poles as pivots, and the half which crosses Greenwich be carried (the nearest way round) till it crosses some other station, then the arc through which it is carried is called the longitude of the station, and the longitude is easterly or westerly according as this half-circle has to be shifted toward the east or west. A complete half-turn is 180°, and, by taking such a half-turn either eastwardly or westwardly, the whole surface of the earth is included. Points which are 180° east of Greenwich are thus also 180° west of Greenwich.

So much is premised in the way of explanation to make the present paper complete; but ten minutes' inspection of an ordinary terrestrial globe will show the true meaning of latitude and longitude more clearly (to those who happen to have forgotten what they learned at school on these points) than any verbal description.

Now, it is sufficiently easy for a sea-captain in fine weather to determine his latitude. For places in different latitudes have different celestial scenery, if one may so describe the aspect of the stellar heavens by night and the course traversed by the sun by day. The height of the pole-star above the horizon, for instance, at once indicates the latitude very closely, and would indicate the latitude exactly if the pole-star were exactly at the pole instead of being merely close to it. But the height of any known star when due south also gives the latitude. For, at every place in a given latitude, a star rises to a given greatest height when due south; if we travel farther south, the star will be higher when due south; if we travel farther north, it will be lower; and thus its observed height shows just how far north of the equator any northerly station is, while, if the traveller is in the Southern Hemisphere, corresponding observations show how far to the south of the equator he is.

But commonly the seaman trusts to observation of the sun to give him his latitude. The observation is made at noon, when the sun is highest above the horizon. The actual height is determined by means of the instrument called the sextant. This instrument need not be here described; but thus much may be mentioned to explain that process of taking the sun's meridian altitude which, no doubt, every one has witnessed who has taken a long sea-journey. The sextant is so devised that the observer can see two objects at once, one directly and the other after reflection of its light; and the amount by which he has to move a certain bar carrying the reflecting arrangement, in order to bring the two objects into view in the same direction, shows him the real divergence of lines drawn from his eye to the two objects. To take the sun's altitude, then, with this instrument, the observer takes the sun as one object and the horizon directly below the sun as the other: he brings them into view together, and then, looking at the sextant to see how much he has had to move the swinging arm which carries the reflecting glasses, he learns how high the sun is. This being done at noon, with proper arrangements to insure that the greatest height then reached by the sun is observed, at once indicates the latitude of the observer. Suppose, for example, he finds the sun to be 40° above the horizon, and the *Nautical Almanac* tells him that, at the time the sun is 10° north of the celestial equator, then he knows that the celestial equator is 30° above the southern horizon. The pole of the heavens is, therefore, 60° above the northern horizon, and the voyager is in 60° north latitude. Of course, in all ordinary cases, the number of degrees is not exact, as I have here for simplicity supposed, and there are some niceties of observation which would have to be taken into account in real work. But the principle of the method is sufficiently indicated by what has been said, and no useful purpose could be served by considering minutiæ.

Unfortunately, the longitude is not determined so readily. The very circumstance which makes the determination of the latitude so simple introduces the great difficulty which exists in finding the longitude. I have said that all places in the same latitude have the same celestial scenery; and precisely for this reason it is difficult to distinguish one such place from another, that is, to find on what part of its particular latitude-circle any place may lie.

If we consider, however, how longitude is measured, and what it really means, we shall readily see where a solution of the difficulty is to be sought. The latitude of a station means how far toward either pole the station is; its longitude means how far *round* the station is from some fixed longitude. But it is by turning round on her axis that the earth causes the changes which we call day and night; and therefore these must happen at different times in places at different distances round. For example, it is clear that, if it is noon at one station, it must be midnight at a station half-way round from the former. And if any one at one station could telegraph to a person at another, "It is exactly noon here," while this latter person knew from his clock or watch that it was exactly midnight where *he* was, then he would know that he was half-way round exactly. He would, in fact, know his longitude from the other station. And so with smaller differences. The earth turns, we know, from west to east—that is, a place lying due west of another is so carried as presently to occupy the place which its easterly neighbor had before occupied, while this last place has gone farther east yet. Let us suppose an hour is the time required to carry a westerly station to the position which had been occupied by a station to the east of it. Then manifestly every celestial phenomenon depending on the earth's turning will occur an hour later at the westerly station. Sunrise and sunset are phenomena of this kind. If I telegraph to a friend at some station far to the west, but in the same latitude, "The sun is rising here," and he finds that he has to wait exactly an hour before the sun rises there, then he knows that he is one hour west of me in longitude, a most inexact yet very convenient and unmistakable way of speaking. As there are twenty-four hours in the day, while a complete circle running through my station and his (and everywhere in the same latitude) is supposed to be divided into 360°, he is 15° (a 24th part of 360) west of me; and, if my station is Greenwich, he is in what we, in England, call 15° west longitude.[1]

But what is true of sunrise and sunset in the same latitudes and different longitudes, is true of noon whatever the latitude may be. And of course it is true of the southing of any known star. Only unfortunately one cannot tell the exact instant when either the sun or a star is due south or at its highest above the horizon. Still, speaking generally, and for the moment limiting our attention to noon, every station toward the west has noon later, while every station toward the east has noon earlier, than Greenwich (or whatever reference station is employed).

I shall presently return to the question how the longitude is to be determined with sufficient exactness for safety in sea-voyages. But I may digress here to note what happens in sea-voyages where the longitude changes. If a voyage is made toward the west, as from England to America, it is manifest that a watch set to Greenwich time will be in advance of the local time as the ship proceeds westward, and will be more and more in advance the farther the ship travels in that direction. For instance, suppose a watch shows Greenwich time; then when it is noon at Greenwich the watch will point to twelve, but it will be an hour before noon at a place 15° west of Greenwich, two hours before noon at a place 30° west, and so on: that is, the watch will point to twelve when it is only eleven o'clock, ten o'clock, and so on, of local time. On arrival at New York, the traveller would find that his watch was nearly five hours fast. Of course the reverse happens in a voyage toward the east. For instance, a watch set to New-York time would be found to be nearly five hours slow, for Greenwich time, when the traveller arrived in England.

In the following passage these effects are humorously illustrated by Mark Twain:

"Young Mr. Blucher, who is from the Far West, and on his first voyage" (from New York to Europe) "was a good deal worried by the constantly-changing 'ship-time.' He was proud of his new watch at first, and used to drag it out promptly when eight bells struck at noon, but he came to look after a while as if he were losing confi-

[1] In this case, he is "at sea" (which, I trust, will not be the case with the reader), and, we may suppose, connected with Greenwich by submarine telegraph in course of being laid. In fact, the position of the Great Eastern throughout her cable-laying journeys, was determined by a method analogous to that sketched above.

dence in it. Seven days out from New York he came on deck, and said with great decision, 'This thing's a swindle!' 'What's a swindle?' 'Why, this watch. I bought her out in Illinois—gave $150 for her, and I thought she was good. And, by George, she *is* good on shore, but somehow she don't keep up her lick here on the water—gets sea-sick, may be. She skips; she runs along regular enough, till half-past eleven, and then all of a sudden she lets down. I've set that old regulator up faster and faster, till I've shoved it clear round, but it don't do any good; she just distances every watch in the ship,[1] and clatters along in a way that's astonishing till it's noon, but them "eight bells" always gets in about ten minutes ahead of her any way. I don't know what to do with her now. She's doing all she can; she's going her best gait, but it won't save her. Now, don't you know there ain't a watch in the ship that's making better time than she is; but what does it signify? When you hear them "eight bells," you'll find her just ten minutes short of her score—sure.' The ship was gaining a full hour every three days, and this fellow was trying to make his watch go fast enough to keep up to her. But, as he had said, he had pushed the regulator up as far as it would go, and the watch was 'on its best gait,' and so nothing was left him but to fold his hands and see the ship beat in the race. We sent him to the captain, and he explained to him the mystery of 'ship-time,' and set his troubled mind at rest. This young man," proceeds Mr. Clemens, *à propos des bottes*, "had asked a great many questions about sea-sickness before we left, and wanted to know what its characteristics were, and how he was to tell when he had it. He found out."

I cannot leave Mark Twain's narrative, however, without gently criticising a passage in which he has allowed his imagination to invent effects of longitude which assuredly were never perceived in any voyage since the ship Argo set out after the Golden Fleece. "We had the phenomenon of a full moon," he says, "located just in the same spot in the heavens, at the same hour every night. The reason of this singular conduct on the part of the moon did not occur to us at first, but it did afterward, when we reflected that we were gaining about twenty minutes every day; because we were going east so fast, we gained just about enough every day to keep along with the moon. It was becoming an old moon to the friends we had left behind us, but to us Joshuas it stood still in the same place, and remained always the same." O Mr. Clemens, Mr. Clemens! In a work of imagination (as the "Innocents Abroad" must, I suppose, be to a great extent considered), a mistake such as that here made is perhaps not a very serious matter; but, suppose some unfortunate compiler of astronomical works should happen to remember this passage, and to state (as a

[1] Because *set* to go "fast." Of course, the other watches on board would be left to go at their usual rate, and simply put forward at noon each day by so many minutes as corresponded to the run eastward since the preceding noon.

compiler would be tolerably sure to do, unless he had a mathematical friend at his elbow) that, by voyaging eastward at such and such a rate, a traveller can always have the moon "full" at night, in what an unpleasant predicament would the mistake have placed him! Such things happen, unfortunately; nay, I have even seen works, in which precisely such mistakes have been made, in use positively as text-books for examinations. On this account, our fiction writers must be careful in introducing science details, lest peradventure science-teachers (save the mark!) be led astray.

It need scarcely be said that no amount of eastwardly voyaging would cause the moon to remain always "full" as seen by the voyager. The moon's phase is the same from whatever part of the earth she may be seen, and she will become "new," that is, pass between the earth and the sun, no matter what voyages may be undertaken by the inhabitants of earth. Mr. Clemens has confounded the monthly motion of the moon with her daily motion. A traveller who could only go fast enough eastward might keep the moon always due south. To do this he would have to travel completely round the earth in a day and (roughly) about 50½ minutes. If he continued this for a whole month, the moon would never leave the southern heavens; but she would not continue "full." In fact, we see that the hour of the day (local time) would be continually changing—since the traveller would not go round once in twenty-four hours (which would be following the sun, and would cause the hour of the day to remain always the same), but in twenty-four hours and the best part of another hour; so that the day would seem to pass on, though very slowly, lasting a lunar month instead of a common day.

Every one who makes a long sea-voyage must have noted the importance attached to moon observations; and many are misled into the supposition that these observations are directly intended for the determination of the longitude (or, which is the same thing in effect, for determining true ship-time). This, however, is a mistake. The latitude can be determined at noon, as we have seen. A rough approximation to the local time can be obtained also, and is commonly obtained, by noting when the sun begins to dip after reaching the highest part of his course above the horizon. But this is necessarily *only* a rough approximation, and quite unsuited for determining the ship's longitude. For the sun's elevation changes very slowly at noon, and no dip can be certainly recognized, even from *terra firma*, far less from a ship, within a few minutes of true noon. A determination of time effected in this way serves very well for the ship's "watches," and accordingly when the sun, so observed, begins to dip, they strike "eight bells" and "make it noon." But it would be a serious matter for the crew if that was made the noon for working the ship's place; for an error of many miles would be inevitable.

The following passage from "Foul Play" illustrates the way in which mistakes have arisen on this point: The hero, who, being a clergyman and a university man, is, of course, a master of every branch of science, is about to distinguish himself before the heroine by working out the position of the ship Proserpine, whose captain is senselessly drunk. After ten days' murky weather, "the sky suddenly cleared, and a rare opportunity occurred to take an observation. Hazel suggested to Wylie, the mate, the propriety of taking advantage of the moment, as the fog-bank out of which they had just emerged would soon envelop them again, and they had not more than an hour or so of such observation available. The man gave a shuffling answer. So he sought the captain in his cabin. He found him in bed. He was dead drunk. On a shelf lay the instruments. These Hazel took, and then looked round for the chronometers. They were safely locked in their cases. He carried the instruments on deck, together with a book of tables, and quietly began to make preparations, at which Wylie, arresting his walk, gazed with utter astonishment" (as well he might).

"'Now, Mr. Wylie, I want the key of the chronometer-cases.'

"'Here is a chronometer, Mr. Hazel,' said Helen, very innocently, 'if that is all you want.'

"Hazel smiled, and explained that a ship's clock is made to keep the most exact time; that he did not require the time of the spot where they were, but Greenwich time. He took the watch, however. It was a large one for a lady to carry; but it was one of Frodsham's masterpieces.

"'Why, Miss Rolleston,' said he, 'this watch must be two hours slow. It marks ten o'clock; it is now nearly mid-day. Ah, I see,' he added, with a smile, 'you have wound it regularly every day, but you have forgotten to set it daily. Indeed, you may be right; it would be a useless trouble, since we change our longitude hourly. Well, let us suppose that this watch shows the exact time at Sydney, as I presume it does, I can work the ship's reckoning from that meridian, instead of that of Greenwich.' And he set about doing it." Wylie, after some angry words with Hazel, brings the chronometers and the charts. Hazel "verified Miss Rolleston's chronometer, and, allowing for difference of time, found it to be accurate. He returned it to her, and proceeded to work on the chart. The men looked on; so did Wylie. After a few moments, Hazel read as follows: 'West longitude 146° 53′ 18″. South latitude 35° 24′. The island of Oparo [1] and the Four Crowns distant 420 miles on the N. N. E.,'" and so on. And, of course, "Miss Rolleston fixed her large, soft eyes on the young clergyman with the undisguised admiration a woman is apt to feel for what she does not understand."

[1] The island fixes the longitude at about 147°, otherwise I should have thought the 4 was a misprint for 7. In longitude 177° west, Sydney time would be about 2 hours slow, but about 4 hours slow in longitude 147° west.

The scene here described corresponds pretty closely, I have little doubt, with one actually witnessed by the novelist, except only that the captain or chief officer made the observations, and that either there had not been ten days' murky weather, or else that in the forenoon, several hours at least before noon, an observation of the sun had been made. The noon observation would give the latitude, and, combined with a forenoon observation, would give the longitude, but *alone* would be practically useless for that purpose. It is curious that the novelist sets the longitude as assigned much more closely than the latitude, and the value given would imply that the ship's time was known within less than a second. This would in any case be impracticable; but, from noon observations, the time could not be learned within a minute at the least. The real fact is, that, to determine true time, the seaman selects, not noon, as is commonly supposed, but a time when the sun is nearly due east or due west. For then the sun's elevation changes most rapidly, and so gives the surest means of determining the time. The reader can easily see the *rationale* of this by considering the case of an ordinary clock-hand. Suppose our only means of telling the time was by noting how high the end of the minute-hand was: then, clearly, we should be apt to make a greater mistake in estimating the time, when the hand was near XII., than at any other time, because then its end changes very slowly in height, and a minute more or less makes very little difference. On the contrary, when the hand was near III. and IX., we could in a very few seconds note any change of the height of its extremity. In one case we could not tell the time within a minute or two; in the other, we could tell it within a few seconds.

But the noon observation would be wanted to complete the determination of the longitude; for, until the latitude was known, the captain would not be aware what apparent path the sun was describing in the heavens, and therefore would not know the time corresponding to any particular solar observation. So that a passenger, curious in watching the captain's work, would be apt to infer that the noon observations gave the longitude, since he would perceive that from them the captain worked out both the longitude and the latitude.

It is curious that another and critical portion of the same entertaining novel is affected by the mistake of the novelist on this subject. After the scuttling of the Proserpine, and other events, Hazel and Miss Rolleston are alone on an island in the Pacific. Hazel seeks to determine their position, as one step toward escape. Now, "you must know that Hazel, as he lay on his back in the boat, had often, in a half-drowsy way, watched the effect of the sun upon the boat's mast: it now stood, a bare pole, and at certain hours acted like the needle of a dial by casting a shadow on the sands. Above all, he could see pretty well, by means of this pole and its shadow, when the sun attained its greatest elevation. He now asked Miss Rolleston to assist him in making this observation exactly. She obeyed his instructions, and, the moment the shadow reached its highest angle and showed the minutest symptom of declension, she said 'Now,' and Hazel called out in a loud voice" (why did he do that?) "'Noon!' 'And forty-nine minutes past eight at Sydney,' said Helen, holding out her chronometer; for she had been sharp enough to get it ready of her own accord. Hazel looked at her and at the watch with amazement and incredulity. 'What?' said he. 'Impossible! You can't have kept Sydney time all this while.' 'And pray why not?' said Helen. 'Have you forgotten that some one praised me for keeping Sydney time? it helped you somehow or other to know where we were.'" After some discussion, in which she shows how natural it was that she should have wound up her watch every night, even when "neither of them expected to see the morning," she asks to be praised. "'Praised!' cried Hazel, excitedly, 'worshipped, you mean. Why, we have got the longitude by means of your chronometer. It is wonderful! It is providential. It is the finger of Heaven. Pen and ink, and let me work it out.'" He was "soon busy calculating the longitude of Godsend Island." What follows is even more curiously erroneous. "'There,' said he. 'Now, the latitude I must guess at by certain combinations. In the first place the slight variation in the length of the days. Then I must try and make a rough calculation of the sun's parallax.'" (It would have been equally to the purpose to have calculated how many cows' tails would reach to the moon.) "'And then my botany will help me a little; spices furnish a clew; there are one or two that will not grow outside the tropic,'" and so on. He finally sets the latitude between the 26th and 33d parallels, a range of nearly 500 miles. The longitude, however, which is much more closely assigned, is wrong altogether, being set at 103½° *west*, as the rest of the story requires. For Godsend Island is within not many days' sail of Valparaiso. The mistake has probably arisen from setting Sydney in *west* longitude instead of *east* longitude, 151° 14′; for the difference of time, 3h. 11m., corresponds within a minute to the difference of longitude between 151° 14′ west and 103½° west.

Mere mistakes of calculation, however, matter little in such cases. They do not affect the interest of a story even in such extreme cases as in "Ivanhoe," where a full century is dropped in such sort that one of Richard I.'s knights holds converse with a contemporary of the Conqueror, who, if my memory deceives me not, was Cœur de Lion's great-great-grandfather. It is a pity, however, that a novelist or indeed any writer should attempt to sketch scientific *methods* with which he is not familiar. No discredit can attach to any person, not an astronomer, who does not understand the astronomical processes for determining latitude and longitude, any more than to one who, not being a lawyer, is unfamiliar with the rules of conveyancing. But, when an attempt is made by a writer of fiction to give an exact description of any technical matter, it is as well to secure correctness by submitting the description to some friend acquainted with the principles of the subject. For, singularly enough, people pay much more attention to these descriptions when met with in novels, than when given in text-books of science, and they thus come to remember thoroughly well precisely what they ought to forget. I think, for instance, that it may not improbably have been some recollection of "Foul Play" which led Mr. Lockyer to make the surprising statement that longitude is determined at sea by comparing chronometer time with local time, which is found "at noon by observing, with the aid of a sextant, when the sun is at the highest point of its path." Our novelists really must not lead the students of astronomy astray in this manner.

It will be clear to the reader, by this time, that the great point in determining the longitude is, to have the true time of Greenwich or some other reference station, in order that, by comparing this time with ship-time, the longitude east or west of the reference station may be ascertained. Ship-time can always be determined by a morning or afternoon observation of the sun, or by observing a known star when toward the east or west, at which time the diurnal motion raises or depresses it most rapidly. The latitude being known, the time of day (any given day) at which the sun or a star should have any particular altitude is known also, and, therefore, conversely, when the altitude of the sun or a star has been noted, the seaman has learned the time of day. But to find Greenwich time is another matter; and, without Greenwich time, ship-time teaches nothing as to the longitude. How is the voyager at sea or in desert places to know the exact time at Greenwich or some other fixed station? We have seen that chronometers are used for this purpose; and chronometers are now made so marvellously perfect in construction that they can be trusted to show true time within a few seconds, under ordinary conditions. But it must not be overlooked that in long voyages a chronometer, however perfect its construction, is more liable to get wrong than at a fixed station. That it is continually tossed and shaken is something, but is not the chief trial to which it is exposed. The great changes of temperature endured, when a ship passes from the temperate latitudes across the torrid zone to the temperate zone again, try a chronometer far more severely than any ordinary form of motion. And then it is to be noted that a very insignificant time-error corresponds to a difference of longitude quite sufficient to occasion a serious error in the ship's estimated position. For this reason and for others, it is desirable to have some means of determining Greenwich time independently of chronometers.

This, in fact, is the famous problem for the solution of which such high rewards were offered and have been given.[1] It was to solve this

[1] For invention of the chronometer, Harrison (a Yorkshire carpenter, and the son of

problem that Whiston, the same who fondly imagined Newton was afraid of him,[1] suggested the use of bombs and mortars; for which Hogarth pilloried him in the celebrated mad-house scene of the Rake's Progress. Of course Whiston had perceived the essential feature of all methods intended for determining the longitude. Any signal which is *recognizable*, no matter by eye or ear, or in whatsoever way, at both stations, the reference station and the station whose longitude is required, must necessarily suffice to convey the time of one station to the other. The absurdity of Whiston's scheme lay in the implied supposition that any form of ordnance could propel rocket-signals far enough to be seen or heard in mid-ocean. Manifestly the only signals available, when telegraphic communication is impossible, are signals in the celestial spaces, for these alone can be discerned simultaneously from widely-distant parts of the earth. It has been to such signals, then, that men of science have turned for the required means of determining longitude.

Galileo was the first to point out that the satellites of Jupiter supply a series of signals which might serve to determine the longitude. When one of these bodies is eclipsed in Jupiter's shadow, or passes out of sight behind Jupiter's disk, or reappears from eclipse or occultation, the phenomenon is one which can be seen from a whole hemisphere of the earth's surface. It is as truly a signal as the appearance or disappearance of a light in ordinary night-signalling. If it can be calculated beforehand that one of these events will take place at any given hour of Greenwich time, then, from whatever spot the phenomenon is observed, it is known there that the Greenwich hour is that indicated. Theoretically, this is a solution of the famous problem; and Galileo, the discoverer of Jupiter's four satellites, thought he had found the means of determining the longitude with great accuracy. Unfortunately, these hopes have not been realized. At sea, indeed, except in the calmest weather, it is impossible to observe the phenomena of Jupiter's satellites, simply because the telescope cannot be directed steadily upon the planet. But even on land Jupiter's satellites afford but imperfect means of guessing at the longitude. For, at present, their motions have not been thoroughly mastered by astronomers, and though the *Nautical Almanac* gives the estimated epochs for the various phenomena of the four satellites,

a carpenter) received £20,000. This sum had been offered for a marine chronometer which would stand the test of two voyages of assigned length. Harrison labored fifty years before he succeeded in meeting the required condition.

[1] Newton, for excellent reasons, had opposed Whiston's election to the Royal Society. Like most small men, Whiston was eager to secure a distinction which, unless spontaneously offered to him, could have conferred no real honor. Accordingly he was amusingly indignant with Newton for opposing him. "Newton perceived," he wrote, "that I could not do as his other darling friends did, that is, learn of him without contradicting him when I differed in opinion from him: he could not in his old age bear such contradiction, and so he was afraid of me the last thirteen years of his life."

yet, owing to the imperfection of the tables, these epochs are often found to be appreciably in error. There is yet another difficulty. The satellites are not mere points, but, being in reality also as large as or larger than our moon, they have disks of appreciable though small dimensions. Accordingly, they do not vanish or reappear instantaneously, but gradually, the process lasting in reality several seconds (a longer or shorter time, according to the particular satellites considered), and the estimated moment of the phenomenon thus comes to depend on the power of the telescope employed, or the skill or the visual powers of the observer, or the condition of the atmosphere, and so on. Accordingly, very little reliance could be placed on such observations as a mean for determining the longitude with any considerable degree of exactness.

No other celestial phenomena present themselves except those depending on the moon's motions.[1] All the planets, as well as the sun and moon, traverse at various rates and in different paths the sphere of the fixed stars. But the moon alone moves with sufficient

[1] If but one star or a few would periodically (and quite regularly) "go out" for a few moments, the intervals between such vanishings being long enough to insure that one would not be mistaken in point of time for the next or following one, then it would be possible to determine Greenwich or other reference time with great exactness. And here one cannot but recognize an argument against the singular theory that the stars were intended simply as lights to adorn our heavens and to be of use to mankind. The teleologists who have adopted this strange view can hardly show how the theory is consistent with the fact that quite readily the stars (or a few of them) might have been so contrived as to give man the means of travelling with much more security over the length and breadth of his domain than is at present possible. In this connection I venture to quote a passage in which Sir John Herschel has touched on the *usefulness* of the stars, in terms which, were they not corrected by other and better-known passages in his writings, might suggest that he had adopted the theory I have just mentioned: "The stars," he said, in an address to the Astronomical Society, in 1827, "are landmarks of the universe; and, amid the endless and complicated fluctuations of our system, seem placed by its Creator as guides and records, not merely to elevate our minds by the contemplation of what is vast, but to teach us to direct our actions by reference to what is immutable in his works. It is indeed hardly possible to over-appreciate their value in this point of view. Every well-determined star, from the moment its place is registered, becomes to the astronomer, the geographer, the navigator, the surveyor, a point of departure which can never deceive or fail him—the same forever and in all places, of a delicacy so extreme as to be a test for every instrument yet invented by man, yet equally adapted for the most ordinary purposes; as available for regulating a town-clock as for conducting a navy to the Indies; as effective for mapping down the intricacies of a petty barony as for adjusting the boundaries of transatlantic empires. When once its place has been thoroughly ascertained, and carefully recorded, the brazen circle with which the useful work was done may moulder, the marble pillar may totter on its base, and the astronomer himself survive only in the gratitude of posterity; but the record remains, and transfuses all its own exactness into every determination which takes it for a groundwork, giving to inferior instruments, nay, even to temporary contrivances, and to the observations of a few weeks or days, all the precision attained originally at the cost of so much time, labor, and expense." It is only necessary, as a corrective to the erroneous ideas which might otherwise be suggested by this somewhat high-flown passage, to quote the following remarks from the work which represented Sir John Her-

rapidity to act as a time indicator for terrestrial voyagers. It is hardly necessary to explain why rapidity of motion is important; but the following illustration may be given for the purpose. The hour-hand of a clock does in reality indicate the minute as well as the hour; yet, owing to the slowness of its motion, we regard the hour-hand as an unsatisfactory time-indicator, and only consider it as showing what hour is in progress. So with the more slowly-moving celestial bodies. They would serve well enough, at least some among them would, to show the *day of the year*, if we could only imagine that such information were ever required from celestial bodies. But it would be hopeless to attempt to ascertain the true time with any degree of accuracy from their motions. Now, the moon really moves with considerable rapidity among the stars.[1] She completes the circuit of the celestial sphere in 27⅓ days (a period less than the common lunation), so that in one day she traverses about 13°, or her own diameter (which is rather more than half a degree), in about an hour. This, astronomically speaking, is very rapid motion; and, as it can be detected in a few seconds by telescopic comparison of the moon's place with that of some fixed star, it serves to show the time within a few seconds, which is precisely what is required by the seaman. Theoretically, all he has to do is, to take the moon's apparent distance from a known star, and also her height and the star's height above the horizon. Thence he can calculate what would be the moon's distance from the star at the moment of observation, if the observer were at the earth's centre. But the *Nautical Almanac* informs him of the precise instant of Greenwich time corresponding to this calculated distance. So he has, what he requires, the true Greenwich time.

It will be manifest that all methods of finding the way at sea, except the rough processes depending on the log and compass, require that the celestial bodies, or some of them, should be seen. Hence it is that cloudy weather, for any considerable length of time, occasions danger, and sometimes leads to shipwreck and loss of life. Of course the captain of a ship proceeds with extreme caution when the weather has long been cloudy, especially if, according to his reckoning, he is drawing near shore. Then the lead comes into play, that by soundings, if possible, the approach to shore may be indicated.

schel's more matured views, his well-known "Outlines of Astronomy:" "For what purpose are we to suppose such magnificent bodies scattered through the abyss of space? Surely not to illuminate our nights, which an additional moon of the thousandth part of the size of our own world would do much better; nor to sparkle as a pageant void of meaning and reality, and bewilder us among vain conjectures. Useful, it is true, they are to man as points of exact and permanent reference, but he must have studied astronomy to little purpose, who can suppose man to be the only object of his Creator's care; or who does not see, in the vast and wonderful apparatus around us, provision for other races of animated beings."

[1] It was this doubtless which led to the distiuction recognized in the book of Job, where the moon is described as "walking in brightness."

Then, also, by day and night, a careful watch is kept for the signs of land. But it sometimes happens that, despite all such precautions, a ship is lost; for there are conditions of weather which, occurring when a ship is nearing shore, render the most careful lookout futile. These conditions may be regarded as included among ordinary sea-risks, by which term are understood all such dangers as would leave a captain blameless if shipwreck occurred. It would be well if no ships were ever lost save from ordinary sea-risks; but, unfortunately, ships are sometimes cast ashore for want of care; either in maintaining due watch as the shore is approached, or taking advantage of opportunities, which may be few and far between, for observing sun, or moon, or stars, as the voyage proceeds. It may safely be said that the greater number of avoidable shipwrecks have been occasioned by the neglect of due care in finding the way at sea.

SECULAR PROPHECY.

ALTHOUGH prophecy is usually supposed to be the special gift of inspiration, nothing comes more glibly from secular pens. Half of the leading articles in the daily newspapers are more or less disguised predictions. The prophecies of the *Times* are more numerous, more confident, and more explicit, than those of Jeremiah or Isaiah. "Secular Prophecy fulfilled" would be a good title for a book written after the model of those old and half-educated divines who zealously looked through Isaiah, Jeremiah, Daniel, and the Apocalypse, for shadowy hints that Hildebrand would enforce celibacy on the clergy of the Latin Church; that Luther would cut up the Christianity of the West into two sections; that Cromwell would sign the death-warrant of Charles I.; and that the Stuarts would become wanderers over the face of the earth. There are still, we believe, devout, mystical, and studious sectaries, who find such events as the disestablishment of the Irish Church and the meeting of the Vatican Council plainly foretold in the book of Revelation. They also find Mr. Gladstone's name written in letters of fire by inspired pens that left their record while the captivity of Babylon was a recent memory, or while Nero was the scourge of the Church. Nay, Dr. Cumming, who is as different from those mystical interpreters as a smart Yankee trader is from Parson Adams, sees that the Prophet Daniel and St. John had a still more minute acquaintance with the home and Continental politics of these latter days. But "Secular Prophecy fulfilled" would show a much more wonderful series of glimpses into the future than we find in the interpretations of Dr. Cumming, and it would certainly bring together a strange set of soothsayers.

Arthur Young, Lord Chesterfield, and William Cobbett, are not exactly the kind of men whom we should expect to find among the prophets. Arthur Young was a shrewd traveller, with a keen eye for leading facts, and a remarkable power of describing what he saw in plain, homely words. Chesterfield was a literary and philosophical dandy, who, richly furnished with the small coin of wisdom, and fearing nothing so much as indecorum, would have been a great teacher if the earth had been a drawing-room. Cobbett was a coarse, rough English farmer, with an extraordinary power of reasoning at the dictate of his prejudices, and with such a faculty of writing racy, vigorous English as excites the admiration and the despair of scholars. It seems almost ludicrous to speak of such men as prophets. And yet Arthur Young foretold the coming of the French Revolution at a time when the foremost men of France did not dream that the greatest of political convulsions was soon to lay low the proudest of monarchies. And the dandified morality of Lord Chesterfield did not prevent him from making a similar prediction. Cobbett made a guess which was still more notable; for, at the beginning of the present century, he foretold the secession of the Southern States. But the most remarkable of all the secular prophets who have spoken to our time is Heine. He might seem, indeed to have been a living irony on the very name of prophet, for he read backward all the sanctities of religion and all the commands of the moral law. Essentially a humorist, to whom life seemed now the saddest of mysteries, and now the most laughable of jokes, he made sport of every thing that he touched. His most fervid English devotee, Mr. Matthew Arnold, is forced to admit that he was profoundly disrespectable. He quarrelled with his best friends for frivolously petty reasons, and he repaid their kindness by writing lampoons which are masterpieces at once of literary skill and of malignity. Neither Voltaire nor Pope scattered calumnies with such a lack of scruple, and Byron himself was not a more persistent or more systematic voluptuary. Yet Heine was so true a prophet that his predictions might have been accounted the work of inspiration if he had been as famed for piety or purity as he was notorious for irreligion and profligacy. He predicted that Germany and France would fight, and that France would be utterly put down. He predicted that the line of fortifications which M. Thiers was then building round Paris would draw to the capital a great hostile army, and that they would crush the city as if they were a contracting iron shroud. He predicted that the Communists would some day get the upper hand in Paris, that they would strike in a spirit of fiendish rage at the statues, the beautiful buildings, and all the other tangible marks of the civilization which they sought to destroy; that they would throw down the Vendôme Column in their hate of the man who had made France the foe of every other people; and that they would further show their execration for his memory by taking his ashes from the Invalides and flinging them into the Seine. All these predictions, save the last, have been fulfilled to the letter, and it would need a bolder prophet than even Heine himself to say that the last will not be verified also. For nothing is more remarkable in France than the success with which the International is teaching the artisans that the first as well as the third Napoleon was the worst enemy of their class. Although they still regard his achievements with pride, they fervently believe that he was the foe of their order, and the acts of the Commune showed their eagerness to insult his name. And there may be another Commune. Intrepid prophets would say that there certainly will be another. If that should happen, it is quite possible that the fanatics of the International may fling the ashes of the great soldier into the Seine to mark their abhorrence of military glory.

Prevost-Paradol was as different from Heine as a gifted voluptuary can be from a polished, fastidious, and decorous gentleman. Yet the refined, reserved, satirical Orleanist, who seemed to be uncomfortable when his hands were not encased in kid gloves, and who was a master of all the literary resources of innuendo, would be as much out of place among the Hebrew prophets as Heine himself. He would find a place, nevertheless, in "Secular Prophecy fulfilled," by reason of the startling exactness with which he foretold the outbreak of the war between his own country and Germany. In a passage which promises to become classic, he said that the two nations were like two trains which, starting from opposite points, and placed on the same line of rails, were driven toward each other at full speed. There must be a collision. The only doubt was, where it would happen, and when, and with what results. De Tocqueville better fulfilled the traditionary idea of a prophet, and there is a startling accuracy in some of the predictions as to the future of France which he flung forth in talking with his friends, and of which we find a partial record in the journal of Mr. Nassau Senior. Eighteen years before the fall of the empire, he predicted that it would wreck itself "in some extravagant foreign enterprise." "War," he added, "would assuredly be its death, but its death would perhaps cost dear." M. Renan also aspires to a place among the prophets, and he has made a prediction which may be a subject of some curiosity when the next pope shall be elected. The Church of Rome will not, he says, be split up by disputes about doctrine. But he does look for a schism, and it will come, he thinks, when some papal election shall be deemed invalid; when there shall be two competing pontiffs, and Europe shall see a renewal of the strife between Rome and Avignon.

It may be said, no doubt, that the verified predictions which we have cited are only stray hits; that the oracles make still more remarkable misses; and that, since guesses about the future are shot off every hour of the day, it would be a marvel if the bull's-eye were not struck sometimes. Such a theory might suffice to account for the hits, if the prophecies were let off in the dark and at random; but that is not the case. It is easy to trace the path along which the mind of Heine or De Tocqueville travelled to the results of the future, and their predictions betray nothing more wonderful than a rare power of drawing correct inferences from confused facts. A set of general rules might be laid down as a guide to prophecy. In the first place, we might give the negative caution that the analogy of past events is misleading, because the same set of conditions does not appear at two different times, and an almost unseen element might suffice to determine an all-important event. Forgetting this fact, Archbishop Manning has ventured into the field of prophecy with the argument that Catholics should not be made uneasy because the pope has lost his temporal power, for they should remember that he has again and again suffered worse calamities, and has then won back all his old authority. Between 1378 and 1418 the Church witnessed the scandal of a schism, in which there were rival popes, and in which Rome and Avignon competed for the mastery. That calamity is worse than any which has come to the Church in our days, yet the Papacy regained its old power and glory. So late as within the present century the temporal power was reduced to nullity by the first Napoleon, and Pius IX. himself had to flee from Rome in the beginning of his reign. Why, then, should not the robber-band of Victor Emmanuel be paralyzed in turn, and the Papacy once more regain its old splendor? Not being ambitious to play the part of prophets, we do not undertake to say whether the Papacy will or will not again climb or be flung into its ancient place, but it is not the less certain that Archbishop Manning's prophecy is a conspicuous example of a false inference. When he argues that a pope in the nineteenth century will again be the temporal ruler of Rome because a pope triumphed over the schism of Avignon in the fifteenth, he forgets that the lapse of centuries has wrought a vast change of conditions. At the end of the fourteenth century a keen onlooker, a Heine or a De Tocqueville, might have confidently foretold that a pope of unquestioned authority would soon govern the historic city of the Papacy, because the political and the social interests of Europe, no less than the piety or superstition of the times, required that the pope should be powerful and free. The current of the age, if we may use the philosophical slang, was running from Avignon to Rome in the fourteenth and fifteenth centuries, and now the current of the age is not less distinctly running against the temporal power. The very reasons which would have led a prophet in 1400 to predict that Rome would again be the unquestioned seat of the Papacy would lead the same soothsayer to affirm in 1873 that the temporal power has been shattered forever.

It is in general causes that we find the guide of prophecy. Mr. Buckle attached so much importance to the physical conditions of a country, the food of a people, the air they breathe, the occupations which they are forced to follow, and the habits of thought which they display, that he undertook to tell the end of a nation from the beginning. Spain was no mystery to him when he remembered that it had originally been a country of volcanoes; that the people had consequently been filled with a dread of the unseen and inscrutable power which reveals itself in convulsions of the earth; that their diseased fear of shadowy influences made them resent the teachings of science, and hence left them an easy prey to the Holy Office and Ignatius Loyola when Luther, Calvin, and Zwingle, drew away from sacerdotalism all the Christianity of Northern Europe. There can be no doubt that Buckle's theory did rest on a basis of truth, and that it erred simply by trying to account for every thing. In fact, it is not specially his doctrine, but simply the rigid and systematized application of a principle which is as old as speculative curiosity. We apply it every day of our lives. If a family go into a badly-drained house, we say the chances are that they will have typhus, diarrhœa, or cholera. If a rich and foolish young man bets largely on the turf, the probability is that he will be ruined. And the statistician comes to help us with a set of tables which throw uncomfortable light on the mechanical character of those mental and moral processes which might seem to be determined by the unprompted bidding of our own wills. Mr. Buckle was no doubt beguiled by a mere dream when he fancied that we could account for every turn and winding in the history of a country if we had only a large knowledge of its general conditions, such as the temperature of the land, the qualities of the soil, the food of the people, and their relations to their neighbors. He paid too little heed to subtle qualities of race, and he did not make sufficient allowance for the disturbing force of men gifted with extraordinary power of brain and will. Still it is a mere truism that the more correctly and fully we know the general condition of a country, the more does mystery vanish from its history, and the successive events tend to take their place in orderly sequence.

It is impossible, however, to prophesy by rule, and such system-mongers as Mr. Buckle would be the most treacherous of all oracles. Their hard and fast canons will not bend into the subtle crevices of human life. Men who are so ostentatiously logical that they cannot do a bit of thinking without the aid of a huge apparatus of sharply-cut principles always lack a keen scent for truth. They blunder by rule when less showy people find their way by mother-wit. Hence they are the worst of all prophets. It was not by counting up how many things tell in one way, and how many tell in another, that Heine and De Tocqueville were able to guess correctly what was coming, but by watching the chief currents of the age, or, as more homely folk would say, by finding out which way the wind was blowing. They had to decide which among many social, religious, or political forces were the strongest, and which would be the most lasting. They had to give a correct decision as to the stability of particular institutions and the strength of popular passions. General rules could not be of much avail, and they had to rely on their knowledge of human nature, their acquaintance with the forces which have been at work in history, and their own sagacity. Most likely Heine could not have given such an explanation of the grounds on which he made his predictions as would have satisfied any average jury of historical students. But he could have said that he knew the working-men of Paris; that his power of poetic sympathy enabled him to see how their minds veered toward socialism, and he also knew what forces were on the side of order; and that a mental comparison of the two made him look with certainty to a ferocious outbreak of democratic passion. Being thus sure that the storm would come, he had next to ask himself which points the lightning would strike, and he looked for the most prominent symbols of kingship, wealth, refinement, and military glory. The Tuileries would be a mark for the fury of the mob, because that was the palace of the man who had destroyed the populace. The public offices must go, because they represented what the *bourgeois* called order and the workmen called tyranny. The Louvre must go, for the mere sake of maddening rich people who took a delight in art. And the Vendôme Column must go, because it glorified a man who was the incarnation of the war-spirit, and who was consequently the worst foe of the working-classes. To a select committee of the House of Commons such reasons would have seemed the dreams of a moon-struck visionary, and they certainly did not admit of being logically defended. No prophecy does. The power of predicting events is the power of guessing, and those guess best who are least dependent on rules, and most gifted with the mother-wit which works with the quietude and unconsciousness of instinct.—*Saturday Review.*

SYMPATHETIC VIBRATIONS IN MACHINERY.[1]

By Prof. J. LOVERING,

OF HARVARD COLLEGE.

AT the meeting of this Association in Burlington, I showed some experiments in illustration of the *optical method* of making sensible the vibrations of the column of air in an organ-pipe. At the Chicago meeting I demonstrated the way in which the vibrations of strings could be studied by the eye in place of the ear, when these strings were attached to tuning-forks with which they could vibrate in sympathy; substituting for the small forks, originally used by Melde,

[1] From the Proceedings of the Twenty-first Meeting of the American Association for the Advancement of Science.

a colossal tuning-fork, the prongs of which were placed between the poles of a powerful electro-magnet. This fork, which interrupted the battery current, at the proper time, by its own motion, was able to put a heavy cord, thirty feet in length, in the most energetic vibration, and for an indefinite time. I propose, at the present time, to speak of those sympathetic vibrations which are pitched so low as not to come within the limits of human ears, but which are felt rather than heard, and to show how they may be seen as well as felt.

All structures, large or small, simple or complex, have a definite rate of vibration, depending on their materials, size, and shape, and as fixed as the fundamental note of a musical cord. They may also vibrate *in parts*, as the cord does, and thus be capable of various increasing rates of vibration, which constitute their harmonics. If one body vibrates, all others in the neighborhood will respond, if the rate of vibration in the first agrees with their own principal or secondary rates of vibration, even when no more substantial bond than the air unites a body with its neighbors. In this way, mechanical disturbances, harmless in their origin, assume a troublesome and perhaps a dangerous character, when they enter bodies all too ready to move at the required rate, and sometimes beyond the sphere of their stability.

When the bridge at Colebrooke Dale (the first iron bridge in the world) was building, a fiddler came along and said to the workmen that he could fiddle their bridge down. The builders thought this boast a fiddle-de-dee, and invited the itinerant musician to fiddle away to his heart's content. One note after another was struck upon the strings until one was found with which the bridge was in sympathy. When the bridge began to shake violently, the incredulous workmen were alarmed at the unexpected result, and ordered the fiddler to stop.

At one time, considerable annoyance was experienced in one of the mills in Lowell, because the walls of the building and the floors were violently shaken by the machinery: so much so that, on certain days, a pail of water would be nearly emptied of its contents, while on other days all was quiet. Upon investigation it appeared that the building shook in response to the motion of the machinery only when that moved at a particular rate, coinciding with one of the harmonics of the structure; and the simple remedy for the trouble consisted in making the machinery move at a little more or a little less speed, so as to put it out of time with the building.

We can easily believe that, in many cases, these violent vibrations will loosen the cement and derange the parts of a building, so that it may afterward fall under the pressure of a weight which otherwise it was fully able to bear, and at a time, possibly, when the machinery is not in motion; and this may have something to do with such accidents as that which happened to the Pemberton Mills in Lawrence. Large trees are uprooted in powerful gales, because the wind comes in gusts; and, if these gusts happen to be timed in accordance with the natural swing of the tree, the effect is irresistible. The slow vibrations which proceed from the largest pipes of a large organ, and which are below the range of musical sounds, are able to shake the walls and floors of a building so as to be felt, if not heard, thereby furnishing a background of noise on which the true musical sounds may be projected.

We have here the reason of the rule observed by marching armies when they cross a bridge; viz., to stop the music, break step, and open column, lest the measured cadence of a condensed mass of men should urge the bridge to vibrate beyond its sphere of cohesion. A neglect of this rule has led to serious accidents. The Broughton bridge, near Manchester, gave way beneath the measured tread of only sixty men who were marching over it. The celebrated engineer, Robert Stephenson, has remarked[1] that there is not so much danger to a bridge, when it is crowded with men or cattle, or if cavalry are passing over it, as when men go over it in marching order. A chain-bridge crosses the river Dordogne on the road to Bordeaux. One of the Stephensons passed over it in 1845, and was so much struck with its defects, although it had been recently erected, that he notified the authorities in regard to them. A few years afterward it gave way when troops were marching over it.[2]

A few years ago, a terrible disaster befell a battalion of French infantry, while crossing the suspension-bridge at Angers, in France. Reiterated warnings were given to the troops to break into sections, as is usually done. But the rain was falling heavily, and, in the hurry of the moment, the orders were disregarded. The bridge, which was only twelve years old, and which had been repaired the year before at a cost of $7,000, fell, and 280 dead bodies were found, besides many who were wounded. Among the killed or drowned were the chief of battalion and four other officers. Many of the guns were bent double, and one musket pierced completely through the body of a soldier. The wholesale slaughter at the bridge of Beresina, in Russia, when Napoleon was retreating from Moscow, in 1812, and his troops crowded upon the bridge and broke it, furnishes a fitting parallel to this great calamity.

When Galileo set a pendulum in strong vibration by blowing on it whenever it was moving away from his mouth, he gave a good illustration of the way in which small but regularly-repeated disturbances grow into consequence. Tyndall tells us that the Swiss muleteers tie up the bells of the mules, for fear that the tinkle should bring an avalanche down. The breaking of a drinking-glass by the human voice, when its fundamental note is sounded, is a well-authenticated feat; and Chladni mentions an innkeeper who frequently repeated the

[1] *Edinburgh Philosophical Journal*, vol. v., p. 255.

[2] Smiles's "Life of Stephenson," p. 390.

experiment for the entertainment of his guests and his own profit. The nightingale is said to kill by the power of its notes. The bark of a dog is able to call forth a response from certain strings of the piano. And a curious passage has been pointed out in the Talmud, which discusses the indemnity to be claimed when a vessel is broken by the voice of a domestic animal. If we enter the domain of music, there is no end to the illustrations which might be given of these sympathetic vibrations. They play a conspicuous part in most musical instruments, and the sounds which these instruments produce would be meagre and ineffective without them.

In the case of vibrations which are simply mechanical, without being audible, or at any rate musical, the following ocular demonstration may be given: A train of wheels, set in motion by a strong spring wound up in a drum, causes an horizontal spindle to revolve with great velocity. Two pieces of apparatus like this are placed at the opposite sides of a room. On the ends of the spindles which face one another are attached buttons about an inch in diameter. The two ends of a piece of white tape are fastened to the rims of these buttons. When the spindles, with the attached buttons, revolve, the two ends of the tape revolve, and in such directions as to prevent the tape from twisting, unless the velocities are different. Even if the two trains of wheels move with unequal velocities, when independent of each other, the motions tend to uniformity when the two spindles are connected by the tape. Now, by moving slightly the apparatus at one end of the room, the tape may be tightened or loosened. If the tape is tightened, its rate of vibration is increased, and, at the same time, the velocity of the spindles is diminished on account of the greater resistance. If the tape is slackened, its rate of vibration is less, and the velocity of the spindles is greater. By this change we can readily bring the fundamental vibration of the tape into unison with the machinery, and then the tape responds by a vibration of great amplitude, visible to all beholders. If we begin gradually to loosen the tape, it soon ceases to respond, on account of the twofold effect already described, until the time comes when the velocity of the machinery accords with the first harmonic of the tape, and the latter divides beautifully into two vibrating segments with a node at the middle. As the tension slowly diminishes, the different harmonics are successively developed, until finally the tape is broken up into numerous segments only an inch or two in length. The eye is as much delighted by this visible music as the ear could be if the vibrations were audible; and the optical demonstration has this advantage, that all may see, while few have musical ears. A tape is preferred to a cord in this experiment, because it is better seen, and any accidental twist it may acquire is less troublesome.

SPECULATION IN SCIENCE.[1]

By Prof. J. LAWRENCE SMITH.

I NOW pass to the second part of my discourse. It is in reference to the methods of modern science—the caution to be observed in pursuing it, if we do not wish to pervert its end by too confident assertions and deductions.

It is a very common attempt, nowadays, for scientists to transcend the limits of their legitimate studies, and in doing this they run into speculations apparently the most unphilosophical, wild, and absurd; quitting the true basis of inductive philosophy, and building up the most curious theories on little else than assertion; speculating upon the merest analogy; adopting the curious views of some metaphysicians, as Edward von Hartmann; striving to work out speculative results by the inductive method of natural science.

And such an example as this is of great value to the reflective mind, teaching caution, and demonstrating the fact that, while the rules by which we are guided in scientific research are far in advance of those of ancient days, we must not conclude that they are perfect by any means. In our modern method of investigation how many conspicuous examples of deception we have had in pursuing even the best method of investigation! Take, for instance, the science of geology, from the time of Werner to the present day. While we always thought we had the true interpretation of the structural phenomena of the globe, as we progressed from year to year, yet how vastly different are our interpretations of the present day from what they were in the time of Werner! In chemistry, the same thing is true. How clearly were all things explained to the chemist of the last century by Phlogiston, which, in the present century, receive no credence, and chemical phenomena are now viewed in an entirely different light!

Lavoisier, in the latter part of the last century, elucidated the phenomena of respiration and the production of animal heat by one of the most beautiful theories, based, to all appearances, upon well-observed facts; yet, at the present day, more delicate observations, and the discovery of the want of balance between the inhaled oxygen and exhaled carbonic acid, subverted that beautiful theory, and we are left entirely without one. It is true we have collated a number of facts in regard to respiration, molecular changes in the tissues, etc., all of which are recognized as having something to do with animal heat; still it is acknowledged that we are incapable of giving any concrete expression to the phenomena of respiration and animal heat as Lavoisier did eighty or ninety years ago.

[1] Abstract of the address before the American Association for the Advancement of Science, at its late meeting in Portland, Me., by the retiring president.

Electricity is the same now as it has ever been, yet it was once spoken of as a fluid, then as a force, now as an energy readily convertible into caloric or mechanical energy; and in what light it will be considered fifty years hence no one can predict.

Now, what I desire to enforce here is, that amid all these changes and revolutions of theories, so called, it is simply man, the interpreter, that has erred, and not Nature; her laws are the same; we simply have not been able to read them correctly, and perhaps never will be.

What, it may be asked, are we to do, then? Must we cease theorizing? Not at all. The lesson to be learned from this is to be more modest in our generalizations; to generalize as far as our carefully-made-out facts will permit us, and no further; check the imagination, and let it not run riot and shipwreck us upon some metaphysical quicksand.

The fact is, it becomes a question whether there is such a thing as pure theory in science. No true scientific theory deserves the name that is not based on verified hypothesis; in fact, it is but a concise interpretation of the deductions of scientific facts. Dumas has well said that theories are like crutches, the strength of them is, to be tested by attempting to walk with them. And I might further add, that very often scientists, who are without sure-footed facts to carry them along, take to these crutches.

It is common to speak of the theory of gravitation, when there is nothing purely hypothetical in connection with the manner in which it was studied; in it we only see a clear generalization of observed laws which govern the mutual attraction of bodies. If at any time Newton did assume an hypothesis, it was only for the purpose of facilitating his calculations: "Newton's passage from the falling of an apple to the falling of a moon was at the outset a leap of the imagination;" but it was this hypothesis, verified by mathematics, which gave to the so-called theory of gravitation its present status.

In regard to light, we are in the habit of connecting with it a pure hypothesis, viz., the impressions of light being produced by emission from luminous bodies, or by the undulation of an all-pervading, attenuated medium; and these hypotheses are to be regarded as probable so long as the phenomena of light are explained by them, and no longer. The failure to explain one single well-observed fact is sufficient to cast doubt upon or subvert any pure hypothesis, as has been the case with the emission theory of light, and may be the fate of the undulatory theory, which, however, up to the present time, serves in all cases.

It is not my object to criticise the speculations of any one or more of the modern scientists who have carried their investigations into the world of the imagination; in fact, it could not be done in a discourse so limited as this, and one only intended as a prologue to the present meeting. But, in order to illustrate this subject of method more fully, I will refer to Darwin, whose name has become synonymous with progressive development and natural selection, which we had thought had died out with Lamarck fifty years ago. In Darwin we have one of those philosophers whose great knowledge of animal and vegetable life is only transcended by his imagination. In fact, he is to be regarded more as a metaphysician with a highly-wrought imagination than as a scientist, although a man having a most wonderful knowledge of the facts of natural history. In England and America we find scientific men of the profoundest intellects differing completely in regard to his logic, analogies, and deductions; and in Germany and France the same thing—in the former of these countries some speculators saying that "his theory is our starting-point," and in France many of her best scientific men not ranking the labors of Darwin with those of pure science. Darwin takes up the law of life, and runs it into progressive development. In doing this, he seems to me to increase the embarrassment which surrounds us on looking into the mysteries of creation. He is not satisfied to leave the laws of life where he finds them, or to pursue their study by logical and inductive reasoning. His method of reasoning will not allow him to remain at rest; he must be moving onward in his unification of the universe. He started with the lower order of animals, and brought them through their various stages of progressive development until he supposed he had touched the confines of man; he then seems to have recoiled, and hesitated to pass the boundary which separated man from the lower order of animals; but he saw that all his previous logic was bad if he stopped there, so man was made from the ape (with which no one can find fault, if the descent be legitimate). This stubborn logic pushes him still further, and he must find some connecting link between that most remarkable property of the human face called expression; so his ingenuity has given us a very curious and readable treatise on that subject. Yet still another step must be taken in this linking together man and the lower order of animals; it is in connection with language; and before long it is not unreasonable to expect another production from that most wonderful and ingenious intellect on the connection between the language of man and the brute creation.

Let us see for a moment what this reasoning from analogy would lead us to. The chemist has as much right to revel in the imaginary formation of sodium from potassium, or iodine and bromine from chlorine, by a process of development, and call it science, as for the naturalist to revel in many of his wild speculations, or for the physicist who studies the stellar space to imagine it permeated by mind as well as light—mind such as has formed the poet, the statesman, or the philosopher. Yet any chemist who would quit his method of investigation, of marking every foot of his advance by some indelible imprint, and go back to the speculations of Albertus Magnus, Roger

Bacon, and other alchemists of former ages, would soon be dropped from the list of chemists and ranked with dreamers and speculators.

What I have said is, in my humble opinion, warranted by the departure Darwin and others have made from true science in their purely speculative studies; and neither he nor any other searcher after truth expects to hazard great and startling opinions without at the same time courting and desiring criticism; yet dissension from his views in no way proves him wrong—it only shows how his ideas impress the minds of other men. And just here let me contrast the daring of Darwin with the position assumed by one of the great French naturalists of the present day, Prof. Quatrefages, in a recent discourse of his on the physical character of the human race. In referring to the question of the first origin of man, he says distinctly that, in his opinion, it is one that belongs not to science; these questions are treated by theologians and philosophers: "Neither here nor at the Museum am I, nor do I wish to be, either a theologian or a philosopher. I am simply a man of science; and it is in the name of comparative physiology, of botanical and zoological geography, of geology and paleontology, in the name of the laws which govern man as well as animals and plants, that I have always spoken." And, studying man as a scientist, he goes on to say: "It is established that man has two grand faculties, of which we find not even a trace among animals. He alone has the moral sentiment of good and evil; he alone believes in a future existence succeeding this natural life; he alone believes in beings superior to himself, that he has never seen, and that are capable of influencing his life for good or evil; in other words, man alone is endowed with morality and religion." Our own distinguished naturalist and associate, Prof. Agassiz, reverts to this theory of evolution in the same positive manner, and with such earnestness and warmth as to call forth severe editorial criticisms, by his speaking of it as a "mere mine of assertions," and the "danger of stretching inferences from a few observations to a wide field;" and he is called upon to collect "real observations to disprove the evolution hypothesis." I would here remark, in defence of my distinguished friend, that scientific investigation will assume a curious phase when its votaries are required to occupy time in looking up facts, and seriously attempting to disprove any and every hypothesis based upon proof, some of it not even rising to the dignity of circumstantial evidence.

I now come to the last point to which I wish to call the attention of the members of the Association in the pursuit of their investigations, and the speculations that these give rise to in their minds. Reference has already been made to the tendency of quitting the physical to revel in the metaphysical, which, however, is not peculiar to this age, for it belonged as well to the times of Plato and Aristotle as it does to ours. More special reference will be made here to the proclivity of the present epoch among philosophers and theologians to be parading science and religion side by side, talking of reconciling science and religion, as if they have ever been unreconciled. Scientists and theologians may have quarrelled, but never science and religion. At dinners they are toasted in the same breath, and calls made on clergymen to respond, who, for fear of giving offence, or lacking the fire and firmness of St. Paul, utter a vast amount of platitudes about the beauty of science and the truth of religion, trembling in their shoes all the time, fearing that science falsely so called may take away their professional calling, instead of uttering in a voice of thunder, like the Boanerges of the Gospel, that the "world by wisdom knew not God." And it never will. Our religion is made so plain by the light of faith that the wayfaring man, though a fool, cannot err therein.

No, gentlemen, I firmly believe that there is less connection between science and religion than there is between jurisprudence and astronomy, and the sooner this is understood the better it will be for both. Religion is based upon revelations as given to us in a book, the contents of which are never changed, and of which there have been no revised or corrected editions since it was first given, except so far as man has interpolated; a book more or less perfectly understood by mankind, but clear and unequivocal in all essential points concerning the relation of man to his Creator; a book that affords practical directions, but no theory; a book of facts, and not of arguments; a book that has been damaged more by theologians than by all the pantheists and atheists that have ever lived and turned their invectives against it—and no one source of mischief on the part of theologians is greater than that of admitting the profound mystery of many parts of it, and almost in the next breath attempting some sort of explanation of these mysteries. The book is just what Richard Whately says it is, viz., "Not the philosophy of the human mind, nor yet the philosophy of the divine nature in itself, but (that which is properly religion) the relation and connection of the two beings—what God is to us, what he has done and will do for us, and what we are to be in regard to him." . . . Let us stick to science, pure, unadulterated science, and leave to religion things which pertain to it; for science and religion are like two mighty rivers flowing toward the same ocean, and, before reaching it, they will meet and mingle their pure streams, and flow together into that vast ocean of truth which encircles the throne of the great Author of all truth, whether pertaining to science or to religion. And I will here, in defence of science, assert that there is a greater proportion of its votaries who now revere and honor religion in its broadest sense, as understood by the Christian world, than that of any other of the learned secular pursuits.

But, before concluding, I cannot refrain from referring to one great event in the history of American science during the past year, as it will doubtless mark an epoch in the development of science in this country. I refer to the noble gift of a noble foreigner to encourage the poor but worthy student of pure science in this country. It is needless for me to insist on the estimation in which Prof. John Tyndall is held among us. We know him to be a man whose heart is as large as his head, both contributing to the cause of science. We regard him as one of the ablest physicists of the time, and one of the most level-headed philosophers that England has ever produced—a man whose intellect is as symmetrical as the circle, with its every point equidistant from the centre. We have been the recipient of former endowments from that land which, we thank God, was our mother-country, for from it we have drawn our language, our liberty, our laws, our literature, our science, and our energy, and without whose wealth our material development would not be what it is at the present day. Count Rumford, the founder of the Royal Society of London, in earlier years endowed a scientific chair in one of our larger universities, and Smithson transferred his fortune to our shores to promote the diffusion of science. Now, while these are noble gifts, yet Count Rumford was giving to his own countrymen—for he was an American—and they were posthumous gifts from men of large fortune. But the one I now refer to was from a man who ranks not with the wealthy, and he laid his offering upon the altar of science in this country with his own hands; and it has been both consecrated and blest by noble words from his own lips; all of which makes the gift a rich treasure to American science; and I think we can assure him that, as the same Anglo-Saxon blood flows in our veins as does in his (tempered, 'tis true, with the Celtic, Teutonic, Latin, etc.), he may expect much from the American student in pure science as the offspring of his gift and his example.

THE GLACIERS AND THEIR INVESTIGATORS.

By Prof. JOHN TYNDALL.

SOON after my return from America, I learned with great concern that a little book of mine, published prior to my departure, had given grave offence to some of the friends and relatives of the late Principal Forbes; and I was specially grieved when informed that the chastisement considered due to this offence was to be administered by gentlemen between whom and myself I had hoped mutual respect and amity would forever reign. We had, it is true, met in conflict on another field; but hostilities had honorably ceased, old wounds had, to all appearance, been healed, and I had no misgiving as to the permanence of the peace established between us.

The genesis of the book referred to is this: At Christmas, 1871, it fell to my lot to give the brief course of "Juvenile Lectures" to which

Faraday for many years before his death lent such an inexpressible charm. The subject of glaciers, which I had never previously treated in a course of lectures, might, it was thought, be rendered pleasant and profitable to a youthful audience. The sight of young people wandering over the glaciers of the Alps with closed eyes, desiring knowledge, but not always finding it, had been a familiar one to me, and I thought it no unworthy task to respond to this desire, and to give such of my young hearers as might visit the Alps an intelligent interest in glacier phenomena.

The course was, therefore, resolved upon; and, to render its value more permanent, I wrote out copious "Notes," had them bound together, and distributed among the boys and girls. Knowing the damage which elementary books, wearily and confusedly written, had done to my own young mind, I tried, to the best of my ability, to confer upon these "Notes" clearness, thoroughness, and life. It was my particular desire that the imaginary pupil chosen for my companion in the Alps, and for whom, odd as it may sound, I entertained a real affection, should rise from the study of the "Notes" with no other feeling than one of attachment and respect for those who had worked upon the glaciers. I therefore avoided all allusion to those sore personal dissensions which, to the detriment of science and of men, had begun fifteen years prior to my connection with the glaciers, and which have been unhappily continued to the present time.

Prof. Youmans, of New York, was then in London, organizing the "International Scientific Series," with which his name and energy are identified. To prove my sympathy for his work, I had given him permission to use my name as one of his probable contributors, the date of my contribution being understood to belong to the distant, and indeed indefinite, future. He, however, read the "Notes," liked them, urged me to expand them a little, and to permit him to publish them as the first volume of his series. His request was aided by that of another friend, and I acceded to it—hence the little book, entitled the "Forms of Water," which the friends and relatives of Principal Forbes have read with so much discontent.

That modest volume has, we are informed, caused an uncontemplated addition to be made to the Life of Principal Forbes, lately published under the triple auspices of Principal Shairp, the successor of Principal Forbes in the College of St. Andrew's, Mr. Adams-Reilly, and Prof. Tait. "It had been our hope," says Principal Shairp, in his preface, "that we might have been allowed to tell our story without reverting to controversies which, we had thought, had been long since extinguished. But, after most of these sheets were in press, a book appeared, in which many of the old charges against Principal Forbes in the matter of the glaciers were, if not openly repeated, not obscurely indicated. Neither the interests of truth, nor justice to the dead, could suffer such remarks to pass unchallenged. How it has been thought best for the present to meet them, I must leave my friend and fellow-laborer, Prof. Tait, to tell."

The book here referred to is the unpretending volume whose blameless advent I have just described.

I have not the honor of knowing Principal Shairp personally, but he will, I trust, permit me to assure him of two things: Firstly, that, in writing my book, I had no notion of rekindling an extinct fire, or of treating with any thing but tenderness the memory of his friend. Secondly, that, had such been my intention, the negative attribute, "not obscure," is hardly the one which he would have chosen to describe the words that I should have employed. But the fact is, the fire was not extinct: the anger of former combats, which I thought spent, was still potential, and my little book was but the finger which pulled the trigger of an already-loaded gun.

Let the book speak for itself. I reproduce here *in extenso* the references to Principal Forbes, which have been translated into "charges" against him by Principal Shairp. Having, in section 20, mentioned the early measurements of glaciers made by Hugi and Agassiz, I continue thus:

"We now approach an epoch in the scientific history of glaciers. Had the first observers been practically acquainted with the instruments of precision used in surveying, accurate measurements of the motion of glaciers would probably have been earlier executed. We are now on the point of seeing such instruments introduced almost simultaneously by M. Agassiz on the glacier of the Unteraar, and by Prof. Forbes on the Mer de Glace. Attempts had been made by M. Escher de la Linth to determine the motion of a series of wooden stakes driven into the Aletsch Glacier, but the melting was so rapid that the stakes soon fell. To remedy this, M. Agassiz, in 1841, undertook the great labor of carrying boring-tools to his 'hotel,' and piercing the Unteraar Glacier at six different places to a depth of ten feet, in a straight line across the glacier. Into the holes six piles were so firmly driven that they remained in the glacier for a year, and, in 1842, the displacements of all six were determined. They were found to be 160 feet, 225 feet, 269 feet, 245 feet, 210 feet, and 125 feet, respectively.

"A great step is here gained. You notice that the middle numbers are the largest. They correspond to the central portion of the glacier. Hence, these measurements conclusively establish, not only the fact of glacier motion, but that the *centre of the glacier, like that of a river, moves more rapidly than the sides.*

"With the aid of trained engineers, M. Agassiz followed up these measurements in subsequent years. His researches are recorded in a work entitled 'Système Glaciaire,' which is accompanied by a very noble Atlas of the Glacier of the Unteraar, published in 1847.

"These determinations were made by means of a theodolite, of which I will give you some notion immediately. The same instrument was employed the same year by the late Principal Forbes upon the Mer de Glace. He established independently the greater central motion. He showed, moreover, that it is not necessary to wait a year, or even a week, to determine the motion of a glacier; with a correctly-adjusted theodolite he was able to determine the motion of various points of the Mer de Glace from day to day. He affirmed, and with truth, that the motion of the glacier might be determined from hour to hour. We shall prove this farther on. Prof. Forbes also triangulated the Mer de Glace, and laid down an excellent map of it. His first observations and his survey are recorded in a celebrated book published in 1843, and entitled 'Travels in the Alps.'

"These observations were also followed up in subsequent years, the results being recorded in a series of detached letters and essays of great interest. These were subsequently collected in a volume entitled 'Occasional Papers on the Theory of Glaciers,' published in 1859. The labors of Agassiz and Forbes are the two chief sources of our knowledge of glacier phenomena."

It would be difficult for an unbiassed person to find in these words any semblance of a "charge" against Principal Forbes. His friends and relatives may be dissatisfied to see the name of M. Agassiz placed first in relation to the question of the quicker central flow of glaciers; but in giving it this position I was guided by the printed data which are open to any writer upon this subject.

I have checked this brief historic statement by consulting again the proper authorities, and this is the result: In 1841 Principal Forbes became the guest of M. Agassiz on the glacier of the Aar; and in a very able article, published some time subsequently in the *Edinburgh Review*, he speaks of "the noble ardor, the generous friendship, the unvarying good temper, the true hospitality" of his host. In order to explain the subsequent action of Principal Forbes, it is necessary to say that the kindly feeling implied in the foregoing words did not continue long to subsist between him and M. Agassiz. I am dealing, however, for the moment with scientific facts, not with personal differences; and, as a matter of indisputable fact, M. Agassiz did, in 1841, incur the labor of boring six holes in a straight line across the glacier of the Aar, of fixing in these holes a series of piles, and of measuring, in 1842, the distance through which the motion of the glacier had carried them. This measurement was made on July 20th; some results of it were communicated to the Academy of Science in Paris on August 1st, and they stand in the "Comptes Rendus" of the Academy as an unquestionable record, from which date can be taken.

But the friends quarrelled. Who was to blame I will not venture here to intimate; but the assumption that M. Agassiz was wholly in the wrong would, I am bound to say, be required to justify the subsequent conduct of Principal Forbes. He was, I gather from the Life, acquainted with the use of surveying instruments; and knowing roughly the annual rate of glacier-motion, he would also know that through the precision attainable with a theodolite, a single day's—probably a single hour's motion—especially in summer, must be discernible. With such knowledge in his possession, as early as June, 1842, and without deeming it necessary to give his host of the Aar any notice of his intention, Principal Forbes repaired to the Mer de Glace, made in the first instance a few rapid measurements at the Montanvert, and in a letter dated from Courmayeur, on July 4th, communicated them to the editor of the Edinburgh *New Philosophical Journal*.

He did not at that time give any numbers expressing the ratio of the side to the central motion of the glacier, but contented himself with announcing the result in these terms: "The central portion of the Mer de Glace moves past the edges in a very considerable proportion, quite contrary to the opinion generally entertained." This communication, as I have said, bears the date of July 4th; but it was first published in the October number of the journal to which it was addressed. My reason, therefore, for mentioning Agassiz first in the "Forms of Water" is, that, apart from all personal complications, his experiment was begun ten months prior to that of his rival, and that he had also two months' priority of publication.

Neither in his "Travels in the Alps," nor in his "Occasional Papers," does Principal Forbes, to my knowledge, make any reference to this communication of Agassiz. I am far from charging him with conscious wrong, or doubting that he justified this reticence to his own mind. But my duty at present lies with objective facts, and not with subjective judgments. And the fact is that, for eighteen years subsequent to this campaign of 1842, Agassiz, as far as the glaciers are concerned, was practically extinguished in England. The labors of the following years failed to gain for him any recognition. His early mistake regarding the quicker motion of the sides of a glacier, and other weaknesses, were duly kept in view; but his positive measurements, and his Atlas, which prove the observations upon the glacier of the Aar to be far more complete than those made upon any other glacier, were never permitted to yield the slightest credit to their author. I am no partisan of Agassiz, but I desire to be just.

Here, then, my case ends as regards the first reference to Principal Forbes, in section 20 of the "Forms of Water."

In section 48 I describe the dirt-bands of the Mer de Glace, and ascribe the discovery of them to Principal Forbes. There can be no thought of a "charge" here.

The next reference that has any bearing upon this discussion occurs in sections 59 and 60 of the "Forms of Water." I quote it fully:

"By none of these writers is the property of viscosity or plasticity ascribed to glacier-ice; the appearances of many glaciers are, however, so suggestive of this idea that we may be sure it would have found more frequent expression were it not in such apparent contradiction with our every-day experience of ice.

"Still the idea found its advocates. In a little book, published in 1773, and entitled 'Picturesque Journey to the Glaciers of Savoy,' Bordier, of Geneva, wrote thus: 'It is now time to look at all these objects with the eyes of reason; to study, in the first place, the position and the progression of glaciers, and to seek the solution of their principal phenomena. At the first aspect of the ice-mountains an observation presents itself, which appears sufficient to explain all. It is that the entire mass of ice is connected together, and presses from above downward after the manner of fluids. Let us, then, regard the ice, not as a mass entirely rigid and immobile, but as a heap of coagulated matter, or as softened wax, flexible and ductile to a certain point.' Here probably for the first time the quality of plasticity is ascribed to the ice of glaciers.

"To us, familiar with the aspect of the glaciers, it must seem strange that this idea once expressed did not at once receive recognition and development. But in those early days explorers were few, and the 'Picturesque Journey' probably but little known, so that the notion of plasticity lay dormant for more than half a century. But Bordier was at length succeeded by a man of far greater scientific grasp and insight than himself. This was Rendu, a Catholic priest and canon when he wrote, and afterward Bishop of Annecy. In 1841 Rendu laid before the Academy of Sciences of Savoy his 'Theory of the Glaciers of Savoy,' a contribution forever memorable in relation to this subject.

"Rendu seized the idea of glacier plasticity with great power and clearness, and followed it resolutely to its consequences. It is not known that he had ever seen the work of Bordier; probably not, as he never mentions it. Let me quote for you some of Rendu's expressions, which, however, fail to give an adequate idea of his insight and precision of thought: 'Between the Mer de Glace and a river there is a resemblance so complete that it is impossible to find in the glacier a circumstance which does not exist in the river. In currents of water the motion is not uniform, either throughout their width or throughout their depth. The friction of the bottom and of the sides, with the action of local hindrances, causes the motion to vary, and only toward the middle of the surface do we obtain the full motion.'

"This reads like a prediction of what has since been established by measurement. Looking at the glacier of Mont Dolent, which resembles a sheaf in form, wide at both ends and narrow in the middle, and reflecting that the upper wide part had become narrow, and the narrow middle part again wide, Rendu observes: 'There is a multitude of facts which seem to necessitate the belief that glacier-ice enjoys a kind of ductility, which enables it to mould itself to its locality, to thin out, to swell, and to contract, as if it were a soft paste.'

"To fully test his conclusions, Rendu required the accurate measurement of glacier motion. Had he added to his other endowments the practical skill of a land-surveyor, he would now be regarded as the prince of glacialists. As it was, he was obliged to be content with imperfect measurements. In one of his excursions he examined the guides regarding the successive positions of a vast rock which he found upon the ice close to the side of the glacier. The mean of five years gave him a motion for this block of forty feet a year.

"Another block, the transport of which he subsequently measured more accurately, gave him a velocity of 400 feet a year. Note his explanation of this discrepancy: 'The enormous difference of these two observations arises from the fact that one block stood near the centre of the glacier, which moves most rapidly, while the other stood near the side, where the ice is held back by friction.' So clear and definite were Rendu's ideas of the plastic motion of glaciers, that, had the question of curvature occurred to him, I entertain no doubt that he would have enunciated beforehand the shifting of the point of maximum motion from side to side across the axis of the glacier (§ 25).

"It is right that you should know that scientific men do not always agree in their estimates of the comparative value of facts and ideas; and it is especially right that you should know that your present tutor attaches a very high value to ideas when they spring from the profound and persistent pondering of superior minds, and are not, as is too often the case, thrown out without the warrant of either deep thought or natural capacity. It is because I believe Rendu's labors fulfil this condition that I ascribe to them so high a value. But, when you become older and better informed, you may differ from me; and I write these words lest you should too readily accept my opinion of Rendu. Judge me, if you care to do so, when your knowledge is matured. I certainly shall not fear your verdict.

"But, much as I prize the prompting idea, and thoroughly as I believe that often in it the force of genius mainly lies, it would, in my opinion, be an error of omission of the gravest kind, and which, if habitual, would insure the ultimate decay of natural knowledge, to neglect verifying our ideas, and giving them outward reality and substance when the means of doing so are at hand. In science, thought, as far as possible, ought to be wedded to fact. This was attempted by Rendu, and in great part accomplished by Agassiz and Forbes.

"Here, indeed, the merits of the distinguished glacialist last named rise conspicuously to view. From the able and earnest advocacy of Prof. Forbes, the public knowledge of this doctrine of glacial plasticity is almost wholly derived. He gave the doctrine a more distinctive form; he first applied the term *viscous* to glacier-ice, and sought to found upon precise measurements a 'viscous theory' of glacier-motion.

"I am here obliged to state facts in their historic sequence. Prof. Forbes, when he began his investigations, was acquainted with the labors of Rendu. In his earliest works upon the Alps he refers to those labors in terms of flattering recognition. But, though, as a matter of fact, Rendu's ideas were there to prompt him, it would be too much to say that he needed their inspiration. Had Rendu not preceded him, he might none the less have grasped the idea of viscosity, executing his measurements, and applying his knowledge to maintain it. Be that as it may, the appearance of Prof. Forbes on the Unteraar Glacier in 1841, and on the Mer de Glace in 1842, and his labors then and subsequently, have given him a name not to be forgotten in the scientific history of glaciers."

Here, again, I have to declare that, in writing thus, I had no notion of "raking up" an old controversy. My object was to render my account historically continuous, and there is not a single word to intimate that I took exception to Principal Forbes's treatment of Rendu. Nay, while placing the bishop in the position he merited, I went out of my way to point out that, in all probability, Principal Forbes required no such antecedent. So desirous was I that no unkind or disparaging word should escape me regarding Principal Forbes, that, had a reasonable objection to the phraseology here used been communicated to me by his friends, I should have altered the whole edition of the work sooner than allow the objectionable matter to appear in it. . . . .

My final reference to Principal Forbes was in § 67 of the "Forms of Water," where the veined structure of glacier-ice is dealt with. Its description by Guyot, who first observed it, is so brief and appropriate that I quoted his account of it. But this was certainly not with a view of damaging the originality of Principal Forbes. In paragraph 474 of my book the observation of the structure upon the glacier of the Aar is thus spoken of: "The blue veins were observed independently three years after M. Guyot had first described them. I say independently, because M. Guyot's description, though written in 1838, remained unprinted, and was unknown in 1841 to the observers on the Aar. These were M. Agassiz and Prof. Forbes. To the question of structure, Prof. Forbes subsequently devoted much attention, and it was mainly his observations and reasonings that gave it the important position now assigned to it in glacier phenomena."

This is the account of Guyot's observation given by Principal Forbes himself. But it may be objected that I am not correct in classing him and Agassiz thus together, and that to Principal Forbes alone belongs the credit of observing the veined structure upon the Aar Glacier. This may be true, but would an impartial writer be justified in ignoring the indignant protests of M. Agassiz and his companions? With regard to the development of the subject, I felt perfectly sure of the merits of Principal Forbes, and did not hesitate to give him the benefit of my conviction.

Such, then, are the grounds of Principal Shairp's complaint quoted at the outset—such the "charges" that I have made "against Principal Forbes," and which the "interests of truth" and "justice to the dead" could not "suffer to pass unchallenged." There is, I submit, no color of reason in such a complaint, and it would never, I am persuaded, have been made had not Principal Shairp and his colleagues found themselves in possession of a document which, though published a dozen years ago by Principal Forbes, was never answered by me, and which, in the belief that I am unable to answer it, is now reproduced for my confutation.

The document here referred to appeared soon after the publication of the "Glaciers of the Alps" in 1860. It is entitled "Reply to Professor Tyndall's Remarks in his Work on the 'Glaciers of the Alps, relating to Rendu's 'Théorie des Glaciers.'" It was obviously written under feelings of great irritation, and, longing for peace, the only public notice I took of it at the time was to say that "I have abstained from answering my distinguished censor, not from inability to do so, but because I thought, and think, that within the limits of the case it is better to submit to misconception than to make science the arena of personal controversy." My critics, however, do not seem to understand that, for the sake of higher occupations, statements may be allowed to pass unchallenged which, were their refutation worth the necessary time, might be blown in shreds to the winds. Of this precise character, I apprehend, are the accusations contained in the republished essay of Principal Forbes, which his friends, professing to know what he would have done were he alive, now challenge me to meet. I accept the challenge, and throw upon them the responsibility of my answer. . . .[1]

Having thus disposed of the two really serious allegations in the reply, I am unwilling to follow it through its minor details, or to spend time in refuting the various intimations of littleness on my part contained in it. The whole reply betrays a state of mental exacerbation which I willingly left to the softening influence of time, and to which, unless forced to it, I shall not recur.

The biographer who has revived this subject speaks of "the numerous controversies into which he" (Principal Forbes) "was dragged." I hardly think the passive verb the appropriate one here. The following momentary glimpse of Principal Forbes's character points to a truer theory of his controversies than that which would refer them to a "drag" external to himself:

"The hasty glance," says this biographer, "which I have been able to bestow upon his less scientific letters has shown me that Forbes attached great importance to mere honorary distinctions, as well as the opinion of others regarding the value of his discoveries. It has opened up a view of a, to me, totally unexpected feature of his character." This is honest, but that the revelation should be "unexpected" is to me surprising. The "love of approbation" here glanced at was in Principal Forbes so strong that he could not bear the least criticism

[1] We omit this portion of the discussion, for lack of space.—EDITOR.

of his work without resenting it as personal. I well remember the late excellent William Hopkins describing to me his astonishment when, at the meeting of the British Association at York, a purely scientific remark of his on Forbes's glacier theory was turned, with sudden acerbity, into a personal matter. It is of a discussion arising out of this remark that Principal Forbes writes thus: "We had a postponed discussion on glaciers on Saturday morning, when Hopkins and I did battle, and I am sorry to say I felt it exceedingly; it discomposed my nerves and made me very uncomfortable indeed, until I was soothed by the minster-service yesterday." [1]

But no amount of "minster-service" could cope with so strong a natural bias, and many a bitter drop fell from the pen of Principal Forbes into the lives of those whom he opposed subsequent to this service at York. On hearing of the paper presented by Mr. Huxley and myself to the Royal Society, he at once jumped to the conclusion that the glaciers were to be made a "regular party question." "All I can do," he says, "is to sit still till the indictment is made out; and I cordially wish my enemy to write a book and print it speedily, as any thing is better than innuendo and suspense." [2] What he meant by "indictment" I do not know; and, with regard to "innuendo," neither of the writers of the paper would be likely to resort to it in preference to plain speaking. The words of a witty philosopher at the time here referred to are significant: "Tyndall," he said, "is beginning with ice, but he will end in hot water." He knew the circumstances, and was able to predict the course of events with the certainty of physical prevision.

The quality referred to by his biographer, and the tendency arising from it to look at things in a personal light, caused his intellect to run rapidly into hypotheses of moral action which had no counterpart in real life. I read with simple amazement his explanation to his friend Mr. Wills of the postponement of the publication of the "Glaciers of the Alps." Some of his supporters in the Council of the Royal Society had proposed him for the Copley Medal, but without success. Had the rules of good taste been observed, he would have known nothing of these discussions; and, knowing them, he ought to have ignored them. But he writes to his friend: "I believe the effect of the struggle, though unsuccessful in its immediate object, will be to render Tyndall and Huxley and their friends more cautious in their further proceedings. For instance, Tyndall's book, again withdrawn from Murray's 'immediate' list, will probably be infinitely more carefully worded relative to Rendu than he first intended." [3]

I should be exceedingly sorry to apply to Principal Forbes the noun-substantive which Byron, in "Childe Harold," applied to Rousseau, but the adjective "self-torturing" is, I fear, only too applicable. His quick imagination suggested chimerical causes for events, but

[1] Life, p. 165. [2] Ibid., p. 369. [3] Ibid., p. 387.

never any thing more chimerical than that here assigned for the postponement of my book and its probable improvement. The "struggle" in the council had no influence upon me, for this good reason, if for no other, that I knew absolutely nothing of the character of the struggle. In *Nature*, for May 22, 1873, Prof. Huxley has effectually disposed of this hypothesis;[1] and those who care to look at the opening sentences of a paper of mine in Mr. Francis Galton's "Vacation Tourists for 1860," will find there indicated another reason for the delay. I may add, that the only part I ever took in relation to Principal Forbes and a medal was to go on one occasion to the Royal Society with the express intention of recommending that he should have one.

The features of character partly revealed by his biographer also explain that tendency on the part of Principal Forbes to bring his own labors into relief, to the manifest danger of toning down the labors of others. This is illustrated by the foot-note appended to page 419. It is also illustrated by his references to Rendu, which, frequent and flattering as they are, left no abiding impression upon the reader's mind. By some qualifying phrase the quotation in each case is deprived of weight; while practical extinction for eighteen years was, as already intimated, the fate of the "generous" and "hospitable" Agassiz.

Toward the close of the "Life" his biographer, while admitting that "to say that Forbes thoroughly explained the behavior of glaciers would be an exaggeration," claims for him that he must "ever stand forward in the history of the question as one of its most effective and scientific promoters." This meed of praise I should be the last to deny him, for I believe it to be perfectly just. To secure it, however, no bitterness of controversy, no depreciation of the services of others, was necessary. One point here needs a moment's clearing up. The word "theory," as regards glaciers, slides incessantly, and without warning, from one into the other of two different senses. It means sometimes the purely physical theory of their formation, structure, and motion, with which the name of Principal Forbes is so largely identified. But it has a wider sense where it embraces the geological action of glaciers on the surface of the globe. For a long time "glacier theory" had reference mainly to the geological phenomena; it was in this sense that the words were employed by Principal Forbes in his article in the *Edinburgh Review*, published in 1842. It is in this sense that they are now habitually applied by M. Agassiz, and in relation to the theory thus defined it is no more than natural for his supporters to assign to M. Agassiz the highest place. I mention this to abolish the mystification which threatens to surround a question which this simple statement will render clear.

I trust I may be permitted to end here. Strong reasons may cause

[1] The words "drift of my statement," employed in Prof. Huxley's letter, ought to be *draft* of my statement.

me to revert to this question, but they must be very strong. I would only warn my readers against the assumption that, if I do not reply to further attack, I am unable to reply to it. The present rejoinder furnishes sufficient proof of the doubtfulness of such a conclusion. There is one darkly-expressed passage in the "Life of Principal Forbes" which may cover something requiring notice. We are informed that he preserved and carefully docketed all letters written to him, and that he retained copies of all his own. It is with regard to this correspondence that his biographer writes thus: "Many extracts, and even entire letters, may be selected which are free from controversy, yet in general these would give but an imperfect notion of the import of the whole. Others again cannot be published at present, because the writers supply him with details of that mysterious wire-pulling which seems to be inseparable from every transaction involving honors (scientific, in common with all others, it is humiliating to confess). The value of this unique series is, however, so great, and its preservation so complete, that it is to be hoped it may be safely deposited (under seal) in the care of some scientific society or institution, to be opened only when all the actors have passed from the scene."

These undignified allusions to "wire-pulling" are perfectly dark to me; but if the letter addressed to Mr. Wills may be taken as a specimen of the entire "series," here referred to, then I agree with the biographer in pronouncing it "unique." Would it not, however, be a manlier course, and a fairer one to those who, writing without *arrière-pensée*, retain no copies of what they write, to let them know, while they are here to take care of themselves, how their reputations are affected by these letters of Principal Forbes? For my own personal part I am prepared to challenge the production of this correspondence *now.*—*Contemporary Review.*

THE MOON.[1]

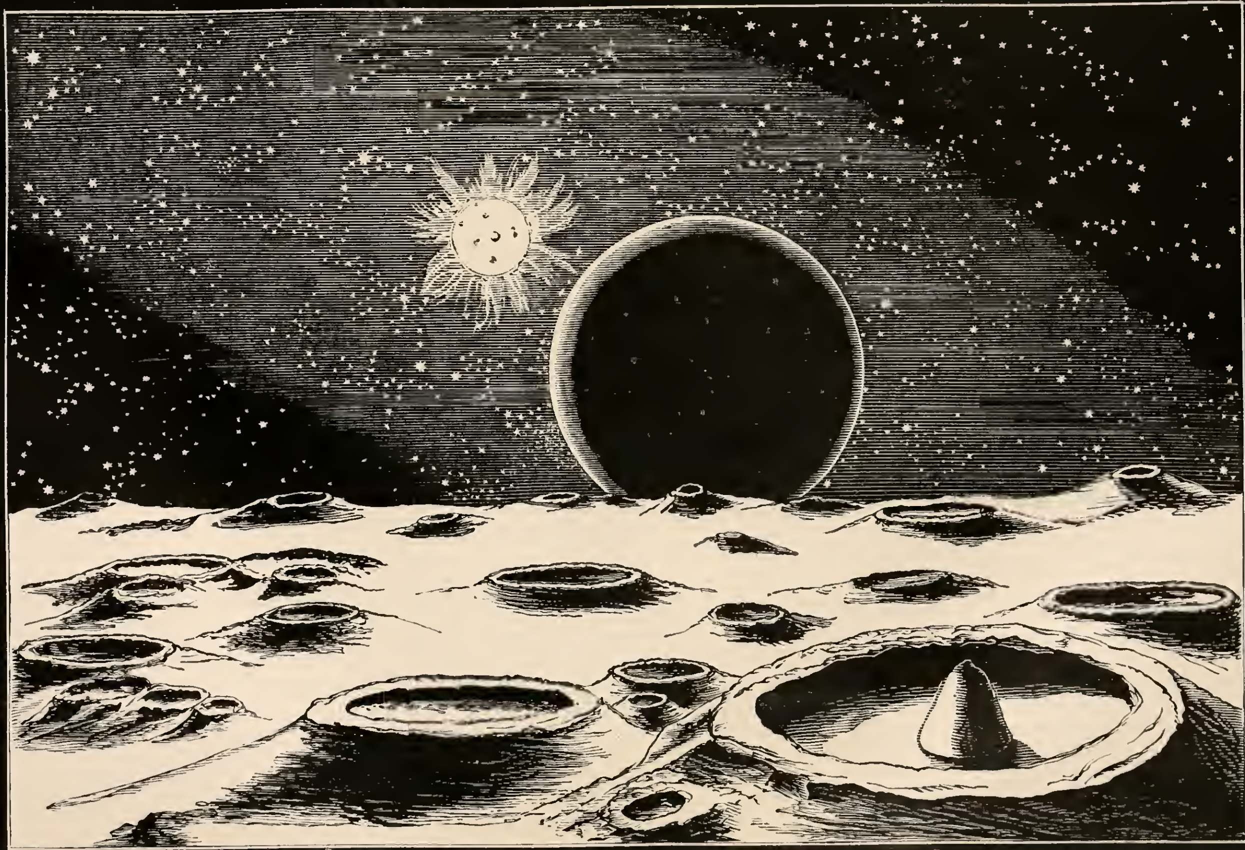
OUR satellite holds a somewhat anomalous position in the literature of astronomy. The most beautiful object in the heavens, the orb which telescopists study under the most favorable conditions, and the planet—for a planet she is—which has afforded the most important information respecting the economy of the universe, she nevertheless has not received that attention from descriptive writers which she really merits. The cause is, perhaps, not far to seek. The beauty of the moon can scarcely be described in words, and cannot be pict-

[1] "The Moon: her Motions, Aspect, Scenery, and Physical Condition." By Richard A. Proctor, B. A., Cambridge (England), Honorary Secretary of the Royal Astronomical Society of London: author of the "Sun," "Saturn," "Other Worlds," etc. New York: D. Appleton & Co. Price, $4.50.

PLATE XXI.

LUNAR LANDSCAPE—"FULL" EARTH.

PLATE XXII.



LUNAR LANDSCAPE—"NEW" EARTH.

ured by the most skilful artist; the information conveyed by the telescope is too definite to permit of speculation as with the other planets, yet not definite enough to solve the questions about which the students of astronomical works take most interest; and the information which astronomers have obtained from the moon's motions can only be appreciated when those motions are thoroughly analyzed, and it has not been found easy to simplify this analysis, that the general reader might fairly be expected to take interest in the matter.

The work before us is intended to remove this long-recognized want in the literature of astronomy. The time has come when this is practicable. The splendid photographs of Rutherford, of New York, and De La Rue, in England, supply the means of exhibiting truthfully the real nature of our satellite's surface. Mr. Proctor has been fortunate in obtaining from Mr. Rutherford permission to use three of his most effective photographs of the moon to illustrate the present work. Recent researches, again, into the processes which are going on within the solar system (so long mistakenly supposed to be unchanging in condition), suggest considerations respecting the past condition of the moon, at once bringing her within the range of speculation and theory. Telescopic observations, also more scrutinizing than those made of yore, and applied more persistently, begin to indicate the possibility at least of recognizing the signs of change, and perhaps of showing that our moon is not the dead and arid waste which astronomers have hitherto supposed her to be. The heat measurements of Lord Rosse also throw important light on the question of her present condition. And then, as respects those points which constitute the main scientific interest of our satellite, her motions under the varying influences to which she is subjected, Mr. Proctor has devoted here his full energies and the results of a long experience, to the endeavor to make clear, even to those who are not mathematicians, the considerations which, weighed and analyzed in the wonderful brain of Newton, supplied the means of demonstrating the theory of the universe.

On this important department of his subject, Mr. Proctor makes the following remarks in his preface: "In Chapter II. I have given a very full account of the peculiarities of the moon's motions; and, notwithstanding the acknowledged difficulty of the subject, I think my account is sufficiently clear and simple to be understood by any one, even though not acquainted with the elements of mathematics, who will be at the pains to read it attentively through. I have sought to make the subject clear to a far wider range of readers than the class for which Sir G. Airy's treatise on 'Gravitation' was written, while yet not omitting any essential points in the argument. In order to combine independence of treatment with exactness and completeness, I first wrote the chapter without consulting any other work. Then I went through it afresh, carefully comparing each section with the corresponding part of Sir G. Airy's 'Gravitation,' and Sir J. Herschel's chapters on the lunar motions in his 'Outlines of Astronomy.' I was thus able to correct any errors in my own work, while in turn I detected a few (mentioned in the notes) in the works referred to. I have adopted a much more complete and exact system of illustration in dealing with the moon's motions than either of my predecessors in the explanation of this subject. I attach great importance to this feature of my explanation, experience having satisfied me not only that such matters should be very freely illustrated, but that the illustrations should aim at correctness of detail, and (wherever practicable) of scale also. Some features, as the advance of the perigee and the retreat of the nodes, have, I believe, never before been illustrated at all."

In Chapter III. Mr. Proctor gives, among other matters, a full explanation of the effects due to the strange balancing motion called the lunar librations. He says: "I have been surprised to find how imperfectly this interesting and important subject has been dealt with hitherto. In fact, I have sought in vain for any discussion of the subject with which to compare my own results. I have, however, in various ways sufficiently tested these results."

But probably, to the greater number of readers, the main interest of the book will be found in the chapters relating to the condition of the moon's surface—the mountains, craters, hills, valleys, which diversify its strange varieties of brightness, color, and tone, and the changes of appearance which are noted as the illumination varies, and as the lunar librations change the position of different regions. It is, by-the-way, to be noted that the moon, which we regard as of silvery whiteness, is in reality more nearly black than white, a fact which will recall to many of our readers a remark of Prof. Tyndall's in the first lecture of the course recently delivered here.

"The moon appears to us," he said, "as if

'Clothed in white samite, mystic, beautiful,'[1]

but, were she covered with the blackest velvet, she would still hang in the heavens as a white orb, shining upon the world substantially as she does now."

Mr. Proctor discusses also the phenomena presented to lunarians, if such there be. The extreme rarity of the lunar atmosphere renders the idea of existence on the moon rather strange to our conceptions, but, as Sir J. Herschel has said in a similar case, "we should do wrong to judge of the fitness or unfitness of" the condition of lunarians "from what we see around us, when perhaps the very combinations which convey to our minds only images of horror may be, in reality, theatres of the most striking and glorious displays of beneficent contrivance." Speaking of the appearances presented by lunar landscapes, two of which we borrow from his work, Mr. Proctor remarks

[1] We quote Tyndall. Tennyson wrote:

"Clothed in white samite, mystic, wonderful."

that "we know far too little respecting the real details of lunar scenery to form any satisfactory opinion on the subject. If a landscape-painter were invited to draw a picture presenting his conceptions of the scenery of a region which he had only viewed from a distance of a hundred miles, he would be under no greater difficulties than the astronomer who undertakes to draw a lunar landscape, as it would actually appear to any one placed on the surface of the moon. We know certain facts—we know that there are striking forms of irregularity, that the shadows must be much darker as well during the lunar day as during an earth-lit lunar light, than on our own earth in sunlight or moonlight, and we know that, whatever features of our own landscapes are certainly due to the action of water in river, rain, or flood, to the action of wind and weather, or to the growth of forms of vegetation with which we are familiar, ought assuredly not to be shown in any lunar landscape. But a multitude of details absolutely necessary for the due presentation of lunar scenery are absolutely unknown to us. Nor is it so easy as many imagine to draw a landscape which shall be correct even as respects the circumstances known to us. For instance, though I have seen many pictures called lunar landscapes, I have never seen one in which there have not been features manifestly due to weathering and to the action of running water. The shadows, again, are never shown as they would be actually seen if regions of the indicated configuration were illuminated by a sun, but not by a sky of light. Again, aërial perspective is never totally abandoned, as it ought to be in any delineation of lunar scenery. I do not profess to have done better myself in the accompanying lunar landscapes. I have, in fact, cared rather to indicate the celestial than the lunarian features shown in these drawings. Still, I have selected a class of lunar objects which may be regarded as, on the whole, more characteristic than the mountain-scenery usually exhibited. And, by picturing the greater part of the landscape as at a considerable distance, I have been freer to reproduce what the telescope actually reveals. In looking at one of these views, the observer must suppose himself stationed at the summit of some very lofty peak, and that the view shows only a very small portion of what would really be seen under such circumstances in any particular direction. The portion of the sky shown in either picture extends only a few degrees from the horizon, as is manifest from the dimensions of the earth's disk; and thus it is shown that only a few degrees of the horizon are included in the landscape."

Our author then pictures the aspect of the lunar heavens by night and by day. We have space but for a few passages from this description: "To an observer stationed upon a summit of the lunar Apennines on the evening of November 1, 1872, a scene was presented unlike any known to the inhabitants of earth. It was near the middle of the long lunar night. On a sky of inky blackness stars innumerable were spread, among which the orbs forming our constellations could be recognized by their superior lustre, but yet were almost lost amid myriads of stars unseen by the inhabitants of earth. Nearly overhead shone the Pleiades, closely girt round by hundreds of lesser lights. From them toward Aldebaran and the clustering Hyades, and onward to the belted Orion, streams and convolutions of stars, interwoven as in fantastic garlands, marked the presence of that mysterious branch-like extension of the Milky-Way which the observer on earth can, with unaided vision, trace no farther than the winged foot of Perseus. High overhead, and toward the north, the Milky-Way shone resplendent, like a vast inclined arch, full 'thick inlaid with patines of bright gold.' Instead of that faint, cloud-like zone known to terrestrial astronomers, the galaxy presented itself as an infinitely complicated star-region—

'With isles of light and silvery streams,
And gloomy griefs of mystic shade.'

"On all sides, this mighty star-belt spread its outlying bands of stars, far away on the one hand toward Lyra and Boötes, where on earth we see no traces of milky lustre, and on the other toward the Twins and the clustering glories of Cancer—the 'dark constellation' of the ancients, but full of telescopic splendors. Most marvellous, too, appeared the great dark gap which lies between the Milky-Way and Taurus; here, in the very heart of the richest region of the heavens—with Orion and the Hyades and Pleiades blazing on one side, and on the other the splendid stream laving the feet of the Twins—there lay a deep, black gulf which seemed like an opening through our star-system into starless depths beyond.

Yet, though the sky was thus aglow with starlight, though stars far fainter than the least we see on the clearest and darkest night were shining in countless myriads, an orb was above the horizon whose light would pale the lustre of our brightest stars. This orb occupied a space on the heavens more than twelve times larger than is occupied by the full moon as we see her. Its light, unlike the moon's, was tinted with beautiful and well-marked colors. . . .

"The globe which thus adorned the lunar sky, and illuminated the lunar lands with a light far exceeding that of the full moon, was our earth. The scene was not unlike that shown to Satan when Uriel—

'One of the seven
Who in God's presence, nearest to the throne,
Stand ready at command"—

pointing earthward from his station amid the splendor of the sun, said to the arch-fiend:

'Look downward on that globe whose hither side
With light from hence, though but reflected, shines:
That place is earth, the seat of man; that light
His day, which else, as th' other hemisphere,
Night would invade.'

"In all other respects the scene presented to the spectator on the moon was similar; but, as seen from the lunar Apennines, the glorious orb of earth shone high in the heavens; and the sun, source of the light then bathing her oceans and continents, lay far down below the level of the lunar horizon. . . .

"Infinitely more wonderful, however, and transcending in sublimity all that the heavens display to the contemplation of the inhabitants of earth, was the scene presented when the sun himself had risen. I shall venture here to borrow some passages from an essay entitled 'A Voyage to the Sun,' in which a friend of mine has described the aspect of the sun as seen from a station outside that atmosphere of ours which veils the chief glories of the luminary of day: 'The sun's orb was more brilliantly white than when seen through the air, but close scrutiny revealed a diminution of brilliancy toward the edge of the disk, which, when fully recognized, presented him at once as the globe he really is. On this globe could be distinguished the spots and the bright streaks called faculæ. This globe was surrounded with the most amazingly complex halo of glory. Close around the bright whiteness of the disk, and shining far more beautiful by contrast with that whiteness than as seen against the black disk of the moon in total eclipses, stood the colored region called the chromatosphere, not *red*, as it appears during eclipses, but gleaming with a mixed lustre of pink and green, through which, from time to time, passed the most startlingly brilliant coruscations of orange and golden yellow light. Above this delicate circle of color towered tall prominences and multitudes of smaller ones. These, like the chromatosphere, were not red, but beautifully variegated. . . .'

"Much more might be said on this inviting subject, only that the requirements of space forbid, obliging me to remember that the moon and not the sun is the subject of this treatise. The reader, therefore, must picture to himself the advance of the sun with his splendid and complicated surroundings toward the earth, suspended almost unchangingly in the heavens, but assuming gradually the crescent form as the sun drew slowly near. He must imagine also how, in the mean time, the star-sphere was slowly moving westward, the constellations of the ecliptic in orderly succession passing behind the earth at a rate slightly exceeding that of the sun's approach, so that he, like the earth, only more slowly, was moving eastward, so far as the star-sphere was concerned, even while the moon's slow diurnal rotation was carrying him westward toward the earth."

In the last chapter the physical condition of the moon's surface is treated, and the processes by which she probably reached her present condition are discussed at considerable length.

EDITOR'S TABLE.

AMERICAN SCIENTIFIC ASSOCIATION—PRESIDENT SMITH'S ADDRESS.

THE twenty-second meeting of the American Association for the Advancement of Science, which commenced at Portland, Me., August 20th, was fairly attended by the members, and presented very good results in the way of scientific work. In estimating its contributions, we must not overlook the fact that, while the numbers of those in this country who are at liberty to pursue original investigations untrammelled, is not large, on the other hand we have two national associations, through which the moderate amount of original research that takes place is published to the world. While the American Association was the only organization of national scope for the publication of new scientific results, its papers were creditable both in number and quality, and it compared favorably with its prototype, the British Association for the Advancement of Science. But, when, a few years ago, a considerable number of its ablest members joined in the organization of the National Academy of Sciences, having substantially the same object in view as the American Association, but exclusive in its membership, and under government patronage, the necessary effect was greatly to weaken the older organization. The National Academy meets twice a year, and draws closely upon the original work of its associates. If, therefore, the numbers in attendance upon the Association and the grade of scientific contributions might seem to indicate a decline in American science, the circumstances here referred to will sufficiently qualify the conclusion.

The address of the retiring president, J. Lawrence Smith, while containing many excellent suggestions, was not conformed to the better type of such productions. It is the custom of the eminent scientific men who are honored with the office but once in their lives to devote the occasion, either to a general review of recent scientific work, or to some special subject with which they are most familiar, and upon which they can speak with the force of authority. Dr. Smith has been favorably known in the world of science as a chemist who has made valuable contributions in its inorganic department. The great activity in chemical inquiries at the present time, and the important transition through which chemical theory is now passing, would certainly have afforded the president a most pertinent and instructive theme, but he preferred to employ the occasion in considering certain aspects of science that are now prominent in public attention, and upon which the scientific world is in much disagreement. The leading feature of the address was an attack on the Darwinians, and this portion of it we publish; and, as the question is thus reopened officially, it becomes a proper subject of comment.

The predecessor of President Smith, Dr. Asa Gray, of Harvard College, had followed the better usage of presiding officers in his address at Dubuque last year, and discussed some of the larger problems of botany in the light of the derivation theory. The most eminent of American botanists, an old and untiring student of the subject, a man of philosophic grasp, and with a candor and sincerity of conviction that commanded the highest respect, after long and thorough study of the question, Prof. Gray did not hesitate to give the weight of his authority to that view of the origin and diversities of living forms of which Mr. Darwin is now the leading representative. And although in the field of biology large numbers of its most eminent students, who are of all men most competent to decide upon it, have accepted that doctrine as representing the truth of Nature more perfectly than any other, and as of immense value in their researches into the laws of life, yet Dr. Smith, as our readers will see, denounces it as a groundless hypothesis due to a riotous imagination, and, in the language of Agassiz, a "mere mire of assertions." His declarations have called forth the applause of the press—always so candid, and intelligent, and independent, on such matters—who seize the occasion to preach new sermons on the "vagaries of science," and declare that they "take sides with the angels against the monkeys," and are "with the Creator against Darwin."

The course of the president was not commended even by his own party. Dr. Newberry, an eminent student of biology and geology, is reported as having spoken in the following decided way: "Prof. Newberry, after a handsome allusion to the retiring president, Prof. J. Lawrence Smith, protested against the opposition to the development theory as expounded in that gentleman's address. Prof. Newberry said he was not himself a Darwinian, but he recognized the value of the evolution theory in science. You cannot measure its value as you can the work of an astronomer, measured by definite ratios of space and time; but he considered the hypothesis one of the most important contributions ever made to a knowledge of Nature. Most men and women are partisans, and some are willing to suppose that the hypothesis is sufficient to account for all the phenomena of the animal kingdom, while, on the other hand, there are those who see in it nothing but failure and deficiency. Let us assume a judicial position, and allow the tests of time and truth to settle the questions involved. Go, however, in whatever direction the facts may lead, and throw prejudice to the winds. Recollect that all truth is consistent with itself."

Dr. Smith can hardly be said to have argued the question of Darwinism. He gave us his own opinion of it, and quoted, to sustain it, two distinguished authorities in natural history. But he gave the influence of his name and position to the charge that it transcends the legitimate limits of inductive inquiry, and is only a wild and absurd speculation. While the technical and difficult questions of natural history by which the truth or falsity of the doctrine must be determined are beyond the reach of unscientific readers, and belong to the biologists to decide, the question here raised as to whether the investigation, as conducted, is legitimately scientific or not, is one of which all intelligent persons ought to be capable of forming a judgment. We have repeatedly considered this point in the pages of The Popular Science Monthly, and have endeavored to show that the present attitude of the doctrine of evolution is precisely the attitude which all the great established theories and laws of science had to take at their first promulgation. It is familiar to all who know any thing of the progress of science, that astronomy and geology, in their early stages, passed through precisely the same ordeal that biology is passing through now; their leading doctrines were reprobated as false science, and the wild dreams of distempered imaginations. Let us now take another case, in the department of pure physics, and see how scientific history repeats itself:

The undulatory theory of light is now a firmly established principle in physics. Dr. Smith says that "the failure to explain one single well-observed fact is sufficient to cast doubt upon, or subvert, any pure hypothesis," and, he adds, in reference to the undulatory theory, that, "up to the present time, it serves in all cases." In order that this theory, now so perfect, should be adopted, it had, of course, to be first propounded. The conception of an ethereal medium to explain the phenomena of light was suggested by Huyghens and Euler, but they did not experimentally demonstrate it, and their authority was overborne by that of Newton, who maintained the emission or corpuscular theory. The true founder of the undulatory hypothesis of light was Dr. Thomas Young, Professor of Natural Philosophy in the Royal Institution of Great Britain, and whom Prof. Tyndall regards as the greatest physicist who has appeared since Newton. Dr. Young is thus estimated by the German Helmholtz: "His was one of the most profound minds that the world has ever seen; but he had the misfortune to be in advance of his age. He excited the wonder of his contemporaries, who, however, were unable to follow him to the heights at which his daring intellect was accustomed to soar. His most important ideas lay, therefore, buried and forgotten in the folios of the Royal Society, until a new generation gradually and painfully made the same discoveries, and proved the exactness of his assertions, and the truth of his demonstrations."

Now, in this case, there was no monkey in the question, and no capital of public prejudice that could be made available in the discussion, to repress obnoxious opinions. The hypothesis was certainly innocent enough, and its truth or falsehood was a matter of simple determination by experiment. Dr. Young made the experiments which established it—the Royal Society recognized the value of the experiments, and, in 1801, assigned to their author the distinguished honor of delivering the Bakerian lecture, in which his experiments were described, and their conclusions demonstrated. Yet, with the Royal Society to back him, and with his views capable of proof before all men, Dr. Young was crushed, and that by outside influences appealing to the public, on the ground that his hypothesis was spurious science—mere wild absurdity of the imagination.

We ask attention to the similarity of the present ground of attack upon Darwin, and the ground of attack upon Dr. Young three-quarters of a century ago. Dr. Smith prefaces his strictures upon Darwinism with the following declaration: "It is a very common attempt nowadays for scientists to transcend the limits of their legitimate studies, and, in doing this, they run into speculations apparently the most unphilosophical, wild, and absurd; quitting the true basis of inductive philosophy, and building up the most curious theories on little else than assertion."

Henry Brougham, afterward Lord-Chancellor of England, writing in the second number of the *Edinburgh Review* concerning Young's Bakerian lecture, said: "We have of late observed in the physical world a most unaccountable predilection for vague hypotheses daily gaining ground; and we are mortified to see that the Royal Society, forgetful of those improvements in science to which it owes its origin, and neglecting the precepts of its most illustrious members, is now, by the publication of such papers, giving the countenance of its highest authority to dangerous relaxations in the principles of physical logic. We wish to raise our feeble voice against innovations that can have no other effect than to check the progress of science, and renew all those wild phantoms of the imagination which Bacon and Newton put to flight from her temple. . . . Has the Royal Society degraded its publications into bulletins of new and fashionable theories for the ladies of the Royal Institution? *Proh pudor!*[1] Let the professor continue to amuse his audience with an endless variety of

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[1] For shame!

such harmless trifles, but, in the name of science, let them not find admittance into that venerable repository which contains the works of Newton and Boyle. . . . The making of an hypothesis is not the discovery of a truth. It is a mere sporting with the subject; it is a sham-fight which may amuse in the moment of idleness and relaxation, but will neither gain victories over prejudice and error, nor extend the empire of science. A mere theory is in truth destitute of merit of every kind, except that of a warm and misguided imagination." Dr. Young's theory "teaches no truth, reconciles no contradictions, arranges no anomalous facts, suggests no new experiments, and leads to no new inquiries. It has not even the pitiful merit of affording an agreeable play to the fancy. It is infinitely more useless, and less ingenious, than the Indian theory of the elephant and tortoise. It may be ranked in the same class with that stupid invention of metaphysical theology. . . . We cannot conclude our review of these articles without entreating for a moment the attention of that illustrious body which has admitted of late years so many paltry and unsubstantial papers into its transactions. . . . We implore the council, if they will deign to cast their eyes upon our humble page, to prevent a degradation of the institution which has so long held the first rank among scientific bodies."

For the second time Dr. Young was selected by the Royal Society to give the Bakerian lecture, and he again chose for its subject "Experiments and Calculations relative to Physical Optics," and again the *Edinburgh Review* came down upon him as follows: "The paper which stands first is another Bakerian lecture, containing more fancies, more blunders, more unfounded hypotheses, more gratuitous fictions, all upon the same field on which Newton trode, and all from the fertile yet fruitless brain of the same eternal Dr. Young." The reviewer thus winds up the controversy: "We now dismiss, for the present, the feeble lucubrations of this author, in which we have searched without success for some traces of learning, acuteness, and ingenuity, that might compensate his evident deficiency in the powers of solid thinking, calm and patient investigation, and successful development of the laws of Nature, by steady and modest observation of her operations. We came to the examination with no other prejudice than the very allowable prepossession against vague hypothesis, by which all true lovers of science have for above a century and a half been swayed. We pursued it, both on the present and on a former occasion, without any feelings except those of regret at the abuse of that time and opportunity which no greater share of talents than Dr. Young's are sufficient to render fruitful by mere diligence and moderation. From us, however, he cannot claim any portion of respect, until he shall alter his mode of proceeding, or change the subject of his lucubrations; and we feel ourselves more particularly called upon to express our disapprobation, because, as distinction has been unwarily bestowed on his labors by the most illustrious of scientific bodies, it is the more necessary that a free protest should be recorded before the more humble tribunals of literature."

The reader will perceive that this strain is not unfamiliar. Young was denounced as Darwin is now denounced, professedly in the interest of science; but the pretext was as false then as it is now. In the former case the *animus* of the assault was mere personal spite: Brougham's inordinate vanity having been wounded by some very moderate criticisms of Dr. Young upon his mathematical works. But a man who did not understand the subject, appealing to a tribunal which knew nothing about it, against wild speculations degrading to science, was able to depreciate and suppress for a quarter of a century one of the most solid and perfect theories of natural phenomena that modern research has produced. And, strange as it may seem, the work was effectually done; for, although Young made a masterly reply, but a single copy was sold, and, as Tyndall remarks, "for twenty years this man of genius was quenched—hidden from the appreciative intellect of his countrymen — deemed, in fact, a dreamer through the vigorous sarcasm of a writer who had then possession of the public ear."

Happily, the time is past when the investigators of Nature can be thus crushed out; but still the old tactics are imitated, and not without evil effect for the time. The men of science, to whom the question belongs, are not left to pursue it in peace. The press and the pulpit, with such scientific help as it is not difficult to get, stir up such a clamor of popular opprobrium that biological students who hold to evolution as the fact and law of Nature, and guide their researches by its light, do not choose to have it publicly known that they are adherents of the doctrine. We are behind England in fair and tolerant treatment of the Darwinian question, but may expect the same improvement in this respect that Huxley tells us has taken place with the English. In a recent article he remarks: "The gradual lapse of time has now separated us by more than a decade from the date of the publication of the 'Origin of Species;' and whatever may be thought or said about Mr. Darwin's doctrines, or the manner in which he has propounded them, this much is certain, that, in a dozen years, the 'Origin of Species' has worked as complete a revolution in biological science as the 'Principia' did in astronomy—and it has done so, because, in the words of Helmholtz, it contains 'an essentially new creative thought.' And, as time has slipped by, a happy change has come over Mr. Darwin's critics. The mixture of ignorance and insolence which, at first, characterized a large proportion of the attacks with which he was assailed, is no longer the sad distinction of anti-Darwinian criticism. Instead of abusive nonsense, which merely discredited its writers, we read essays, which are, at worst, more or less intelligent and appreciative; while, sometimes, like that which appeared in the *North British Review* for 1867, they have a real and permanent value."

THE EDUCATIONAL CONVENTION AT ELMIRA.

THE national educational association recently held at Elmira, N. Y., was of unusual interest, and evinced a marked progress in the public method of dealing with educational subjects. We have for some years refrained from attendance upon teachers' conventions, having been wearied with the narrow technical range and pedantic pettiness of the discussions. But the recent meeting showed that educators are beginning to outgrow their old professional limitations, and to consider the various questions that come before them in the light of broad principles, and in the spirit of radical and rational improvement. Many men of ability, presidents of leading colleges, eminent professors, principals of high-schools, and State and city superintendents, were present, contributing valuable papers, and giving strength and character to the debates which followed them.

President McCosh delivered an able address on the higher education, and maintained that the national Government should not give the balance of its lands to the agricultural colleges, nor yet to other collegiate institutions, but should appropriate them for the benefit of high-schools and academies throughout the country. Dr. McCosh thus stated his main position:

"I don't propose that any portion of this $90,000,000 should be given to colleges. We cannot aid all, and to select a few would be injurious. In regard to elementary education, the Northern, the Middle, and the Western States, are able and willing to do their duty. I venture to propose that in these the unappropriated lands be devoted to the encouragement of secondary schools. Let each State obtain its share, and the money handed over to it under certain rigid rules and restrictions to prevent the abuse of the public money. In particular, to secure that upper schools be endowed only where needed, I suggest that money be allocated only when a district, or, it may be, a combination of two or more districts, has raised a certain portion, say one-half, of the necessary funds. By this means the money may be made to stimulate the erection of high-schools all over America. These schools would aid colleges far more powerfully than a direct grant to them, as, in fact, the grand difficulty which colleges have to contend against arises from there being so few schools fitted to prepare young men for them with their rising standard of excellence. But I plead for these schools, not merely as a means of feeding colleges, but as competent to give a high education in varied branches, literary and scientific, to a far greater number who do not go on to any thing higher. These schools, like the elementary schools, should be open to all children, of the poor as well as the rich. They should be set up, like the German gymnasium, in convenient localities, so that all the population may have access to them. They should embrace every useful branch suited to young men and women under sixteen and eighteen years of age—English composition, English language, history, classics, modern language, and elementary science. The best scholars in our primary schools would be drafted up to these higher schools, and thus the young talent of the country would be turned to good account, while the teachers in the common schools would be encouraged by seeing their best pupils advance."

The discussion that followed this speech brought out difficulties which the doctor had not considered, and, in fact, opened the way to the most vital problem of American education. The colleges of the country represent the old scholastic culture which took its shape at a period when popular education was not thought of, and culture was confined to the professional classes. These institutions are not holding their own at the present time. Their students are falling off, for the reason that there is a decline in the academies by which the colleges are fed; that is, as Dr. McCosh says, "the grand difficulty which colleges have to contend against arises from there being so few schools fitted to prepare young men for them."

But the cause of the decline of the academies is the rivalry of the newly-instituted high-schools, and these are the outgrowth and now an essential part of the common-school system. The modern idea of universal education has become organized in such a way as to antagonize the old college system. The common schools are not constructed upon the scholastic pattern; they aim to give to all a useful practical education, that shall be available in the common work of life. It was found that they did not go far enough in this direction for the wants of many, and so high-schools were organized in which the pupils of the common schools might graduate into the working world with a better preparation than the lower schools can furnish. It was stated in the discussion that but one in fifteen hundred of the population passes through college, while it is left for the common and high schools to educate the rest of the people. As the old academies disappear, therefore, the colleges seek to get control of the high-schools, to be used as feeders for themselves; and this, of course, necessitates a high-school curriculum fitted to prepare young men for college. This is the point at which the two systems are unconformable, and is to be the point of conflict in the future. What shall be the course of study in the high-schools? Shall it be a sequel to the common schools, or a prelude to the colleges, for these are different things? Already in some of them we have two distinct systems of education. A principal of one of these institutions in the West said to the writer: "We are working under the disadvantages of a double curriculum. We have a scheme of studies, scientific and practical, drawn with reference to the larger number of our pupils who come from the common schools, and who close their studies with us. We take them through an English course, with mathematics, book-keeping, political economy, physics, chemistry, botany, and physiology. And we have also a classical course for a small number of students who are preparing for college. But the exactions of Latin and Greek are so great upon these that they get hardly a smattering of the subjects pursued by the other students." The tactics of Dr. McCosh were admirable. To keep the proceeds of the public lands from going to the agricultural colleges and scientific institutions, he is willing to resign all claim upon them for the benefit of the classical colleges; at the same time, if the money is expended for the extension of high-schools, as the doctor says, "these schools would aid colleges far more powerfully than a direct grant to them." Yet, as long as the two systems of education remain so diverse that the regular high-school graduation is not accepted as preparation for college, there will be conflict for the control of these establishments. Only as the college curriculum becomes more broad, modern, and scientific, and the classical studies are restricted to the special classes who have need of them, can American education become harmonized in its elements and unified in its system.

The report of President Eliot, of Harvard, on a national university, was a strong document. We publish the last portion of it, which deals with the main question, and ask attention to the high grounds on which he bases his demand for the non-interference of government with the system of higher education. His paper started a warm debate on the broad and important question of the proper relations of government to the work of instruction, and, of course, his views met with vigorous opposition. It was maintained that there is no break in the logic by which government action is prescribed; and that, admitting the propriety of state action in primary education, there is no halting-place until the government takes charge of the entire school machinery of the country. And such is the overshadowing influence of politics, and so profound the superstition regarding government omnipotence, that this view found its urgent advocates, who seem blind to the consequences that are certain to follow when the people shirk the responsibilities of attending directly to the education of the young, and shoulder it off upon a mass of politicians holding the offices of government. The friends of state education certainly pressed their case to its extreme conclusions. Government contributes money to support common schools, and appoints officers to regulate them; therefore let it appropriate $20,000,000 to establish a national university at Washington, with $1,000,000 a year to be divided among the congressional appointees, who will hold the professorships. Dr. McCosh suggested that recent congressional experiences were hardly calculated to inspire confidence in the action of that body, and asked what guarantee we should have against a university ring and systematic educational jobbing; and it was objected by others that the class of men who congregate in the capital, and the whole spirit of the place, would make it more unfit than any other in the country for such an institution. Prof. Richards, of Washington, came to the rescue of the reputation of his town, and asked, emphatically, "Where do its knaves and rascals come from? *We* do not make them; you send them to us from all parts of the nation." But the argument was not helped by the retort, for it is quite immaterial whether Washington breeds its scoundrels or imports them. If our republican system is one that sifts out its most venal and unscrupulous intriguers and sharpers, and gathers them into one place, it is questionable whether that place had better not be avoided as the seat of a great model university—especially if said intriguers and sharpers are to have the management of it.

ELECTIVE STUDIES AT HARVARD.

In an instructive article upon this subject, the *Nation* says: "There was a vague but very general impression, a few years ago, that, if the elective system were introduced into the older American colleges, the practical sciences, as they are called, especially physics, chemistry, and natural history, would crowd out the study of the ancient languages. There was also a feeling that the obvious utility of the modern languages, and particularly of French and of German, would help to throw the "dead languages" into the background. A great many enthusiasts fancied that the good time a-coming was at hand, when books would be thrown aside, and all intellectual activity would be narrowed down to the study of physical Nature; and so much noise has been made about the natural sciences that a great many people undoubtedly think this is the principal if not the only subject taught where an elective system prevails."

To submit this matter to a test, and "ascertain what it is that the mass of students feel the need of most and flock to most when the choice is left entirely to themselves," the *Nation* overhauls the university catalogue of Harvard for 1872–'73, and presents the statistics which bear upon the subject. The "elections" of subjects of study or choices of the students are shown in a succession of tables, the last of which divides the college studies into "disciplinary" and "practical," and exhibits the results as follows:

DISCIPLINARY STUDIES.	
Ancient languages	100
History	37
Mathematics	21
Philosophy	15
Political science	12
	185
PRACTICAL STUDIES.	
Modern languages	80
Physics and chemistry	37
Natural history	28
	145

"By this arrangement the disciplinary studies preponderate over the practical in the ratio of 185:145 or 100:78."

Upon this the *Nation* proceeds to remark: "The figures show conclusively that, in spite of the crusade which has been carried on against the ancient languages, they are still full of vitality, still a power, still a popular study, and, in fact, the greatest interest in the little college world. As our inquiry is purely numerical and statistical, we do not ask why the students make the selections they do. Doubtless, the reasons are not very obvious; still, one fact is plain, that they are not guided wholly by utilitarian views."

Now, if the *Nation* had looked a little into the "why" of this matter, we are sure it would have found the reasons for this state of things obvious enough, and, although it might have somewhat qualified its conclusion, it would have made the statement more valuable. The number of votes cast at an election is usually an expression of public opinion, but, if in any case there happen to have been military interference and dictation, the numerical report of ballots cast, if taken alone, would be misleading. We are told that the working of the option system at Harvard affords an indication of the preferences and tendencies of the students in regard to the studies they incline to pursue; but is not entrance to Harvard a part of its policy, and what about the option *there?* Is there not at the door of the university a big winnowing-machine which delivers the "disciplinary" studies as acceptable wheat, and blows the "utilitarian" studies to the winds as the veriest chaff? All the preparation exacted of students for entrance to college is in the "disciplinary" studies, and mainly in the Latin and Greek languages. Besides being incessantly told in the preparatory schools that the very poles of the intellectual world are two dead languages, and that a classical education is the only real broad liberal education, they are kept for years drilling at Latin and Greek as the only condition upon which they can get to college at all. The standard is here kept as high as it was twenty years ago, and President Eliot stated at the late Elmira convention that, in the estimation of the preparatory teachers in New England, Harvard requires a year more study of Latin and Greek than the other colleges. The student thus enters college warped and biassed by his preparation for it. Of the sciences he knows nothing, and he is prejudiced against them as mere utilitarian studies to be contrasted on all occasions with liberal mental pursuits. When these facts are remembered, it is certainly no matter of surprise that Latin and Greek lead in the collegiate elections of study; it is rather surprising that they lead by so small a number. It is very far from being a fair or open choice when a pupil has to repudiate his past acquisitions, and stem the tide of opinion which has forced them upon him, to take up studies under the grave disadvantage of no early preparation. We think the lesson of the Harvard statistics is not altogether exhilarating to the partisans of the classics. When Harvard will accept a scientific preparation for college as of equal value with the classical, we shall be better prepared to estimate the strength of the tendencies in the two directions.

LIFE OF PRINCIPAL FORBES.

The biographer of Sir Walter Scott alludes to a "first love" which ended unfortunately for the great romancer. It is related that, rain happening to fall one Sunday after church-time, Scott offered his umbrella to a young lady, and, the tender having been accepted, he escorted her to her home. The acquaintance was continued, and ripened into a strong attachment on the part of Scott; but he was doomed to disappointment, and Lockhart states that it produced a profound effect upon his character. "Keble, in a beautiful essay on Scott, more than hints a belief that it was this imaginary regret haunting Scott all his life long which became the true well-spring of his inspiration in all his minstrelsy and romance." Be that as it may, the lady, whose name was Williamina Belches, instead of marrying Scott, chose his friend, Sir William Forbes. They had a family, of which the youngest, James David, was born in 1809. When the son was nineteen years old his father died, and, under the immediate influence of the bereavement, he drew up a set of brief resolutions for the regulation of his life, one of which was "to curb pride and over-anxiety in the pursuit of worldly objects, especially fame." Young Forbes became a famous man. He took to science, and mastered it rapidly under the guidance of his intimate friend Sir David Brewster, choosing physics as his department. At the death of Sir John Leslie, Professor of Natural Philosophy in the University of Edinburgh, he offered himself as a candidate for the chair, in opposition to his old friend Brewster and others, and was elected to the position at the age of twenty-four. He was an original investigator in a wide field of physics, contributed to the extension of knowledge in many directions, and was an able writer. His health failing, he resigned his chair in the Edinburgh University, and accepted the principalship of St. Andrew's, and is therefore known as Principal Forbes. He died the last day of 1868, and an elaborate biography, by three of his Scotch friends, has just been published by Macmillan, which is an extremely interesting book.

Among other subjects of his investigation were the glaciers, upon which he published an important volume. He met Agassiz in the Alps, while that gentleman was experimenting upon glacial motions, and they made observations together, but subsequently fell out with each other about the division of the honors of discovery. The complication extended, involving the claims of Bishop Rendu, Prof. Guyot, and others. In his "Glaciers of the Alps," published in 1860, Prof. Tyndall undertook to do justice to the claims of all parties. Prof. Forbes was not satisfied with the awards, and replied to Prof. Tyndall's work, vindicating his own claims to a larger share of the investigation than had been accorded him. To this Prof. Tyndall at the time made no rejoinder; but in his recently-published "Forms of Water" he restated the case in a way that was not satisfactory to Forbes's biographers, who have met it by an appendix to the volume. In the *Contemporary Review* for August, Prof. Tyndall returns to the question in an elaborate paper, entitled "Principal Forbes and his Biographers," of which we publish the first and last portions, that are of most general interest. We have not space for the whole article, which is long, and omitted the extended extracts from Rendu's work in French, and that portion of the argument which will mainly concern the special students of glacial literature. In an introductory note to the article, Prof. Tyndall briefly states the origin and cause of the controversy, and earnestly deprecates its present revival. He says, speaking of the biographers: "I am challenged to meet their criticisms, which, I find, are considered to be conclusive by some able public journals and magazines. Thus the attitude of a controversialist is once more forced upon me. Since the death of Principal Forbes no one has heard me utter a word inconsistent with tenderness for his memory; and it is with an unwillingness amounting to repugnance that I now defend myself across his grave. His biographers profess to know what he would have done were he alive, and hold themselves to be the simple executors of his will. I cannot act entirely upon this assumption, or deal with the dead as I should with the living. Hence, though these pages may appear to some to be sufficiently full, they lack the completeness, and still more the strength, which I should have sought to confer upon them had my present position been forced upon me by Principal Forbes himself instead of by his friends."

It is to be feared that Prof. Forbes did not sufficiently abide by the rule of life which was formed under the solemn circumstances of his father's death.

We commend to the attention of our scientific readers, with philosophical inclinations, the series of articles on "The Primary Concepts of Modern Physical Science," the first of which appears this month, on "The Theory of the Atomic Constitution of Matter." The depth and force of the criticism are only equalled by the clearness of the conceptions, and the precision and felicity of the statement. The interest of the discussion will not be lessened when we say that it is by an Ohio lawyer—formerly a judge of Cincinnati. It has been held as one of the redeeming features of the English bar, that the author of the able and admirable essay on "The Correlation of Forces" belongs to it; and it is certainly to the credit of the legal profession in this country that a member of it has cultivated physical philosophy to such excellent purpose as is evinced by the article we now publish.

LITERARY NOTICES.

The Unity of Natural Phenomena. A Popular Introduction to the Study of the Forces of Nature. From the French of M. Emile Saigey. With an Introduction and Notes by Thomas Freeman Moses, A. M., M. D. Boston: Estes & Lauréat. Price $1.50. 253 pages.

Although this neat and attractive little volume claims to be a popular introduction to the study of the forces of Nature, we think it should rather be regarded as a book for those who have been previously introduced to the subject. It is rather devoted to an exposition of the author's speculative views than to a simplified and elementary statement for those who are beginning to study. The author holds to a universal ether, and maintains besides that matter is constituted from it, and consists of it, and he aims to build up the universe of ethereal atoms and motion. The work is written from the modern point of view of the correlation of forces, and contains much interesting information upon this subject, but the author is less concerned merely to interpret the phenomena of interaction among the forces than to get below them to what he regards as the causes of their unity. "The atom and motion, behold the universe!" is a somewhat Frenchy and fantastic cosmology. To readers of a speculative turn of mind the book will prove interesting.

Sanitary Engineering: a Guide to the Construction of Works of Sewerage and House-Drainage. By Baldwin Latham, C. E. 352 pages. Price $12. New York: E. & F. N. Spon.

This work is in all respects a contrast to that of M. Saigey. Instead of transcendental ether, it treats of descendental sewerage, and, instead of remote imaginative speculations, it is occupied with the most immediate and practical of the interests of daily life. Of the importance of the subject treated, the preservation of life and health by the thorough construction of sanitary works, there can be no question, and the author claims that it is the first book exclusively devoted to subjects relating to sanitary engineering. He has gathered his material from official reports, periodical papers, and various works which touch the subject incidentally, and, adding to them the results of his own practice, has produced a most valuable treatise. As science unravels the complicated conditions of life, it becomes more and more apparent that health can only be maintained by the destruction or thorough removal of those deleterious products which are engendered in dwellings. The necessity of drainage is well understood, and the art has been long practised in all civilized countries; but, like all other arts, its intelligent and efficient practice depends upon scientific principles, and therefore progresses with a growing knowledge of the subject. The questions involved in the proper sewerage of a district are numerous. Its geological character and physical features have to be considered; the meteorological element of rainfall is important; the constitution of the soil and subsoil must be taken into account; the sources and extent of artificial water-supply are of moment; and the area of the district to be sewered, and its present and prospective population, cannot be overlooked. Much information of this kind requires also to be called into requisition in the construction of separate country-residences. The physical circumstances being given, there then arise numerous questions in regard to drainage, construction, household contrivances, the materials employed, and the cost, efficiency, and permanency of works. Mr. Latham's volume treats this whole series of topics in a systematic and exhaustive way. It is profusely illustrated with woodcuts and maps, and contains numerous tables which are indispensable for the guidance of constructors. It is not reprinted, but is supplied by the New-York branch of the London house, who hold it at an exorbitant pice.

Myths and Myth-Makers: Old Tales and Superstitions interpreted by Comparative Mythology. By John Fiske. Price, $2.00. Boston: James R. Osgood & Co., 1873.

Travellers to the United States, and American authors themselves, have often remarked on the affectionate veneration shown by Americans for the oldest things in Europe, and for all the associations connecting their present life with the life of their forefathers in the old country. Not long ago, it may be remembered, the builders of a new meeting-house at Boston (United States), sent for a brick from the prototype still standing at our Boston in England. We now find an officer of Harvard University putting forth labor which is evidently a labor of love, and the literary skill and taste in which the best American writers set an example worth commending to many of ours; and the things he speaks of belong to the Old World; to a world, indeed, so far off that for centuries we had lost its meaning, and have only just learned to spell it out again. His theme takes him back from the New World, not only to England, not only to Europe, but to the ancient home of the Aryan race, a world still full of wonders for the dwellers in it, whose changes of days and seasons, interpreted by the analogy of human will and action, were instinct with manifold life; where the imagination of our fathers shaped the splendid and gracious forms which have gone forth over the earth, as their children went forth, and prevailed in many lands, and have lived on through all the diverse fates of the kindred peoples in India, in Greece, in Iceland, to bear witness in the latter days to the unity of the parent stock. This book, which Mr. Fiske modestly introduces as a "somewhat rambling and unsystematic series of papers," seems to us to give the leading results of comparative mythology in a happier manner and with greater success than has yet been attained in so small a compass. It is the work of a student who follows in the steps of the great leaders with right-minded appreciation, and who, though he does not make any claim to originality, is no ordinary compiler. He is enthusiastic in his pursuit, without being a fanatic; his style has the attractiveness, due to a certain subtle tact or refinement hard to analyze, but quite sensibly felt, which marks the best American essay-writing; and his manner of dealing with his subject is well fitted to reassure those who have been deterred from seeking any acquaintance with comparative mythology, either by the formidable appearance of philological apparatus and Vedic proper names, or by the aggressive boldness of one or two champions of the new learning. It is very natural to feel a rebellious impulse at being told that half the gods and heroes of the classical epics, or even the nursery tales, which have delighted us from our youth up, are sun and sky, light and darkness, summer and winter, in various disguises.

The myth is in its origin neither an allegory—as Bacon and many others have thought—nor a metaphor—as seems now and then to be implied in the language of modern comparative mythologists—but a genuinely-accepted explanation of facts, a "theorem of primitive Aryan science," as Mr. Fiske happily expresses it. This view is brought out in the last essay of the volume, entitled "The Primeval Ghost World," where the genesis of mythology is held not to be explicable by the science of language alone, and is rather ascribed to the complete absence of distinction between animate and inanimate Nature, which is now known to be common to all tribes of men in a primitive condition, and to which Mr. Tylor has given the name of Animism. We are pleased to find Mr. Fiske praising Mr. Tylor's work warmly, and even enthusiastically: here is another of the many proofs that the ties of common language and culture are in the long-run stronger than diplomacy and Indirect Claims. We find mentioned, among other instances of animism, the belief that a man's shadow is a sort of ghost or other self. This belief has, in comparatively-recent times, made its mark even in so civilized a tongue as the Greek. Στοιχειὸ in Romaic is a ghost, or rather a personified object generally, and seems to correspond exactly to the *other self* attributed by primitive man to all creatures, living or not living, indiscriminately. Mr. Geldart, in a note to his book on Modern Greek (Oxford, 1870), which well deserves the attention of students of language and mythology, traces this as well as older allied meanings from the original meaning of στοιχεῖον in classical Greek, as the shadow on the sun-dial, acutely observing that the moving shadow would seem to the natural man far more alive and mysterious than the fixed rod.

There are several matters dealt with in special chapters by Mr. Fiske which we must put off with little more than allusion: the book is indeed a small one, but so full of interest that choice among its contents is not easy. An essay on "The Descent of Fire" treats of the divining-rod and other talismans endowed with the faculty of rending open rocks and revealing hidden treasure, which all appear to be symbols, sometimes obvious, sometimes remotely and fancifully derived, of the lightning which breaks the cloud and lets loose the treasures of the rain. There is also a chapter on the mythology of non-Aryan tribes, showing the difference between the vague resemblance of these to Aryan myths and to one another, and the close family likeness which leads to the certain conclusion that the great mass of Aryan mythology came from a common stock.—*Spectator.*

Home and School: A Journal of Popular Education. Morton & Co., Louisville.

In a late number of this journal is an excellent article by Prof. Alexander Hogg, of the Alabama Agricultural and Mechanical College, entitled "More Geometry—less Arithmetic," that contains various suggestions worthy the thoughtful attention of teachers. It was a favorite idea of the late Josiah Holbrook, which he enforced upon educators on all occasions, that rudimentary geometry should be introduced into all primary schools; but he insisted with equal earnestness upon his theory of their order, which was embodied in his aphorism, "Drawing before writing, and geometry before arithmetic." The priority of geometrical or arithmetical conception in the unfolding mind is a subtle psychological question, into which it is not necessary for the teacher to go, the practical question being to get a recognition of the larger claims of geometry, and this is the point to which Prof. Hogg wisely directs the discussion. The fact is, mental development has been too much considered in its linear and successive aspects, and the theories that are laid down concerning the true order of studies have been hitherto too much confined to this idea. Starting with inherited aptitudes, mental development begins in the intercourse of the infant mind with the environment, and, while it is true that there is a sequence of mental experience in each increasing complexity, it is equally true that many kinds of mental action are unfolded together. Ideas of form are certainly among the earliest, and therefore should have an early cultivation. To all that Prof. Hogg says about the need of increasing the amount of geometry in education we cordially subscribe, and we think he is equally right in condemning the excess of attention that is given to arithmetic, which is mainly due to its supposed practical character as a preparation for business. But neither is geometry without its important practical uses. The professor says:

"Let us see, then, what a pupil with enough arithmetic and the plane geometry can perform. He can measure heights and distances; determine areas; knows that, having enclosed *one* acre with a certain amount of fencing, to enclose *four* acres he only has to *double* the amount of fencing; that the same is true of his buildings. In circles, in round plats, or in cylindrical vessels, he will see a beautiful, universal law pervading the whole—the increase of the circumference is proportional to the increase of the diameter, while the increase of the circle is as the *square* of the diameter. . . .

"Thousands of boys are stuffed to repletion with 'interest,' 'discount,' and 'partnership,' in which they have experienced much 'loss' but no 'profit;' have mastered as many as *five* arithmetics, and yet, upon being sent into the surveyor's office, machine-shop, and carpenter-shop, could not erect a perpendicular to a straight line, or find the centre of a circle already described, if their lives depended upon it. Many eminent teachers think that young persons are incapable of reasoning, and that the truths of geometry are too abstruse to be comprehended by them. . . .

"Children are taught to read, not for

what is contained in the reading-books, but that they may be able to read through life; so, let enough of the leading branches be taught, if no more, to enable the pupil to pursue whatever he may need most in after-life. Let, then, an amount of geometry commensurate with its importance be taught even in the common schools; let it be taught at the same time with arithmetic; let as much time be given to it, and we shall find thousands who, instead of closing their mathematical books on leaving school, will be led to pursue the higher mathematics in their maturer years."

The Mystery of Matter and Other Essays. By J. Allanson Picton. 12mo, pp. 482. Price $3.50. Macmillan & Co.

The purpose of this work is to reconcile the essential principles of religious faith with the present tendencies of thought in the sphere of positive and physical science. Mr. Picton is not a votary of modern skepticism, although he recognizes the fact of its existence, and its bearing on vital questions. Nor is he a partisan of any of the current systems of philosophy or science, but discusses their various pretensions in the spirit of intelligent and impartial criticism. He has no fear of their progress or influence; he accepts many of their conclusions; he honors the earnestness and ability of their expounders; while he believes that their results are in harmony with the essential ideas of religion. It is possible, he affirms, that all forms of finite existence may be reduced to modes of motion. But this is of no consequence in a religious point of view, for motion itself is only the visible manifestation of the energy of an infinite life. "To me," he says, "the doctrine of an eternal continuity of development has no terrors; for, believing matter to be in its ultimate essence spiritual, I see in every cosmic revolution a 'change from glory to glory, as by the Spirit of the Lord.' I can look down the uncreated, unbeginning past, without the sickness of bewildered faith. I want no silent dark eternity in which no world was; for I am a disciple of One who said, 'My Father worketh hitherto.' My sense of eternal order is no longer jarred by the sudden appearance in the universe of a dead, inane substance, foreign to God and spiritual being. And if, with a true insight, I could stand so high above the world as to take any comprehensive survey of its unceasing evolutions—here a nebula dawning at the silent fiat 'be light,' there the populous globe, where the communion of the many with the One brings the creature back to the Creator—I am sure that the oneness of the vision, so far from degrading, would unspeakably elevate my sense of the dignity and blessedness of created being. I have no temptation, therefore, to join in cursing the discoverer who tracks the chain of divine forces by which finite consciousness has been brought to take its present form; because I know he can never find more than that which was in the beginning, and is, and ever shall be—the 'power of an endless life.'"

With regard to the speculations of Prof. Huxley, the author, so far from bewailing their effects, pronounces them decidedly favorable to the interests of religion. They present a formidable barrier to the encroachments of materialism. In this respect, he thinks that Prof. Huxley has rendered services to the Church, if less signal, not less valuable, than those which he has rendered to science. He has brought the religious world face to face with facts with a vigor and a clearness peculiar to himself. Not only so. In the opinion of the author, he has made suggestions concerning those facts of vast importance to the future of religion. He has defined the only terms on which harmony is possible between spiritual religion and physical science. Equalling Berkeley in transparent distinctness of statement, while he far surpasses him in knowledge of physical phenomena, Mr. Huxley has shown that, whether we start with materialism or idealism, we are brought at length to the same point. He has thus proved himself one of the most powerful opponents that materialism ever had. All that he did in his celebrated discourse on the "Physical Basis of Life" was, to call attention to certain indisputable facts. "And perhaps it was the impossibility of denying these facts which was a main cause of the uneasiness that most of us felt. Thus he told us that all organizations, from the lichen up to the man, are all composed mainly of one sort of matter, which in all cases, even those at the extremity of the scale, is almost identical in composition. And the one other fact on which he insisted was, that every living action, from the vibrations of cilia by the foraminifer to the imagination of Hamlet or the composition of the Messiah, is accompanied by, and in a sense finds an equivalent expression in, a definite waste or disintegration of material tissue. Thus it is no less certain that the muscles of a horse are strained by a heavy load, than it is that the brain of a Shakespeare undergoes molecular agitation, producing definite chemical results, in the sublime effort of imagination."

But, at first blush, such statements produce a shock in the minds of most readers. They are reluctant to be told that the soul never acts by itself apart from some excitement of bodily tissue. It seems monstrous that thought and love, which in one direction find their expression in the majesty of eloquence, should in another direction find their expression in evolving carbonic acid and water. Such a union between soul and body seemed to amount to identity. And yet the soul was conscious that, whatever might be said, it was not one of the chemical elements, nor all of them put together.

The mental anxiety referred to has been aggravated by the hold which has been taken on most inquiring minds, by the doctrine of development. Whether natural selection is or is not sufficient to account for the origin of species, the idea of successive acts of creation out of nothing has been virtually abandoned by all whose observations of Nature have been on such a scale as to entitle their opinions to any weight. What was once the property of a few isolated thinkers has been made completely accessible to minds of common intelligence. But the terrors which have been awakened by the popular reception of novel scientific theories are entirely founded on the assumption that matter and spirit are fundamentally distinct in their nature. It has been the general belief that matter was something heavy, lifeless, inert, something that forms the hidden basis of the ethereal vision of the world. But, argues the author, if that assumption be the mere creature of false analogy, and is wholly incongruous and unthinkable, it does not indeed follow that materialism, in a fair sense of the word, is impossible, still the conclusion cannot be avoided that materialism and spiritualism would then exhibit only different aspects of the same everlasting fact, and physical research might henceforth unfold to us only the energies of Infinite Life self-governed by eternal law.

But, admitting the universal action of molecular mechanics, the author adduces numerous instances which show that the explanation they offer of the phenomena of sensation cannot be realized in consciousness. Nothing is really an explanation which cannot be reproduced in consciousness as such. We demand a cause from which the effect can rationally be educed. The perception of distance, for example, is explained by the action of the muscular sense and the experience of touch. This is an adequate explanation, for it can be realized in consciousness. But the case is far otherwise with the explanation of sensation by molecular mechanics. Physical research lands us in a dead inert substance called matter, which, though without soul or meaning in itself, produces by its vibrations the most beautiful visions and sublime emotions in our consciousness. But the external phenomena, inseparable from our consciousness of sight or sound, cannot be rationally connected with the consciousness that gives them all their interest. No one to whom the Hallelujah Chorus utters the joy of heaven, or for whom a sonata of Beethoven gives a voice to the unutterable, can make it seem real to himself that his mind is invaded by mere waves of vibrating air. At no point in the chain of vibrations, not even the point most deeply buried in the brain, can we conceive that molecular action is converted into any thing besides material movement, or resistance to movement. But this does not exhaust the consciousness. The emotional, imaginative, and moral wealth of human life opens a world of reality immeasurably greater than can be contained in mere mechanical movement.

Assuming, then, the fact of a nature in man, of which the molecular laws are not the substance, but the condition, the author takes up the inquiry as to the essential nature of religion. This he defines to be the endeavor after a practical expression of man's conscious relation to the Infinite. The savage who wonders at the unseen but mighty wind that streams from unknown realms of power has already the germ of the feeling which inspires religion. But the conscious relation to the Infinite includes every stage in this consciousness, just as the name of a plant includes the blade as well as the fruit. If the evolution of religion be a normal phase in the development of mankind, there must be at the root of it that grand and measureless Power which is the inevitable complement of the conception of evolution. All evolution implies a divine Power, but religious evolution has to do with the dim apprehension of that Power in consciousness. Mr. Herbert Spencer, to continue the reasoning of the author, has been much blamed, by many religious thinkers, for making the reconciliation between science and religion to lie in the recognition on both sides that "the Power which the universe manifests to us is utterly inscrutable." Yet the very persons who most strenuously object to this suggestion are in the habit of quoting the words of Scripture which declare the unsearchable mystery of the Divine Nature. Those words are used to rebuke the arrogance of philosophy. But, when philosophy learns the lesson, its humility is condemned as wilful blindness. The true philosophy of ignorance, however, retains as an indestructible element of human consciousness an apprehension of something beyond all fragmentary existence, the Absolute Being, at once the only true substance, and the One that constitutes a universe from the phenomenal world. It is inevitable that attempts should be made to give practical expression to this feeling. And in such efforts we find the first germs of religion.

With the imperfect summary which we have given of the views maintained in this volume, it will be perceived that its position in literature is that of a commentary on new developments of thought, rather than of a complete exposition of any system of philosophy or science. Accepting the consequences of modern physical research, it aims to establish their consistency with the principles of a high religious faith, and thus to remove the vague alarms which their prevalence has called forth in certain portions of the community. The author is evidently a man of an ardent poetical temperament, of a reverent and tender spirit, and an aptitude for illustration rather than for demonstration.—*N. Y. Tribune.*

Chimneys for Furnaces, Fireplaces, and Steam-Boilers. By R. Armstrong, C. E., 12mo, 76 pages. Price, 50 cents.

This is number one of Van Nostrand's science series, and is a technological monograph that will be useful to engineers and builders. The author says: "Furnaces or closed fireplaces, which it is the main design of this essay to treat upon, are essentially different in principle and construction to the ordinary open fireplaces of dwelling-houses, as they are exceedingly different in their general scope and object, and in the vast variety of their applications;" and he then proceeds to expound the general philosophy of special chimneys for furnaces and steam-boilers.

Steam-Boiler Explosions. By Zerah Colburn. 12mo, 98 pages. New York: D. Van Nostrand.

This is number two of the same series, and is a most instructive and readable essay. The editor states that, although published ten years ago, later experiences would add but little if any thing to the knowledge it affords. The various observed scientific questions in regard to the causes of steam-boiler explosions, such as over-heating, electricity, the spheroidal state, decomposed steam, etc., are considered, but Mr. Colburn maintains that, whether these are valid causes of explosion or not, they are collectively as nothing compared with the one great cause—defective boilers. The style in which this essay is written is a model of simplicity and clearness.

Bulletin of the Buffalo Society of Natural Sciences. Vol. I., Nos. 1 and 2. Buffalo, 1873.

The Buffalo Society of Natural Sciences commences this year the publication of their *Bulletin*, which it is proposed to continue, four numbers to be issued annually. The two numbers before us contain seven papers, six of which are devoted to the describing and cataloguing of American moths, and one gives descriptions of new species of fungi. The author of the latter paper is Charles H. Peck; all the others are by Augustus R. Grote. Mr. Grote is well known to entomologists as an authority on the subjects which he discusses, and the Buffalo society is to be congratulated for being the medium through which the laborious and valuable researches of so able a naturalist are published to the world. The papers are strictly scientific and technical, being intended solely for those who pursue methodically the special branches of science to which they refer. They are not *popular* expositions, but rather brief notes on certain departments of natural science, to be understood and valued only by the initiated. The *Bulletin* is handsomely printed on good paper, in octavo form. Subscription price, $2.50 per volume.

Atmospheric Theory of the Open Polar Sea: with Remarks on the Present State of the Question. By William W. Wheildon. First Paper. Boston, 1872.

This paper was read at the meeting of the American Association for the Advancement of Science, held at Newport, R. I., in 1860, and was published in the volume of proceedings of the Association for that year. The extraordinary interest taken in Arctic affairs during the past two years has led to its reissue in pamphlet form, with brief introductory observations on the present state of the problem. Accepting the view, now quite generally held, that an open sea, or at least a much ameliorated climate, exists in the vicinity of the pole, the author, in this paper, aims to show that such a condition of things "is largely if not entirely due to the currents of the air from the equatorial regions which move in the higher strata of the earth's atmosphere, bearing heat and moisture with them." How well he succeeds in this undertaking, we leave the readers of the argument to judge.

BOOKS RECEIVED.

Washington Catalogue of Stars. By order of Rear-Admiral Sands, U. S. N. Washington, 1873.

First Annual Report of the Minnesota State Board of Health. St. Paul, 1873, pp. 102.

Scientific and Industrial Education. A Lecture. By G. B. Stebbins. Detroit, 1873, pp. 24.

The Railroads of the United States. By Henry V. Poor. New York: H. V. & H. W. Poor, 68 Broadway, pp. 29.

Cosmical and Molecular Harmonics, No. II. By Pliny Earle Chase, M. A. Philadelphia, 1873, pp. 16.

Nickel. By Dr. Lewis Feuchtwanger, pp. 19.

Diminution of Water on the Earth, and its Permament Conversion into Solid Forms. By Mrs. George W. Houk. Dayton, O., 1873, pp. 39.

Sixth Annual Report of the Trustees of the Peabody Museum of American Archæology and Ethnology. Cambridge, 1873, pp. 27. Mr. Gillman's report of his explorations of the ancient mounds on the St. Clair River is an important contribution to archæology. The museum is in a flourishing state, and growing steadily. The Niccolucci collection of ancient crania and implements was the most important addition made during the past year.

MISCELLANY.

Utilization of Waste Coal.—The *English Mechanic* gives an historical sketch of the various processes suggested for the utilization of the waste of coal-mines. From this account it would appear that so early as the close of the sixteenth century the waste of small coal attracted notice. About the year 1594 one Sir Hugh Platt proposed a mixture of coal-dust and loam, together with such combustible materials as sawdust and tanners' bark: the loam being the cement which was to hold the other ingredients together. But Sir Hugh's suggestions did not receive much attention in those early times, when coal was but little used, wood being the staple fuel of England.

It was only at the beginning of the present century that this question began to receive serious attention. A patent was then granted for a mixture of refuse coal with charcoal, wood, breeze, tan, peat, sawdust, cork-cuttings, and other inflammable ingredients. A capital objection to such a scheme is its expense. The product would necessarily cost about as much per ton as good coal, without being at all as serviceable. The next attempt was the production of "gaseous coke." Here the object was to convert small coal, by the addition of coal-tar, either pure, or mixed with naphtha, into a well-mixed mass. It was then to be put into an oven and coked; afterward it was to be broken into suitable blocks for use. There were several modifications of this process, but as they all more or less involved the previous manufacture of their most essential ingredient, coal-tar, the anticipations of the projectors were not realized.

In 1823 a step was taken in the right direction by the combination of bituminous and anthracite coals, and converting them, by partial carbonization in an oven, into a kind of soft coke. In 1845 Frederick Ransome introduced a plan for cementing together small coal by means of a solution of silica dissolved in caustic soda, the small refuse coal so treated to be then compressed into blocks suitable for use. In 1849 Henry Bessemer proposed simply to heat small coal sufficient to soften it, and thus render it capable of being easily pressed into moulds and formed into solid blocks. The coal, according to this plan, might be softened either by the action of steam or in suitable ovens. Coal alone was used, no extraneous matter of any kind being employed. In 1856 F. Ransome brought forward one of the best plans yet offered. He placed the small coal in suitable moulds, which were then passed into an oven, and there heated just sufficiently to cause the mass to agglomerate.

Though the writer in the *Mechanic* commends highly the Ransome and the Bessemer plans, it is clear that they do not fully solve the problem, for inventors are still busy on both sides of the Atlantic devising other and better methods. Perhaps, however, the successful working of the Cranston "Automatic Reverberatory Furnace," which is adapted for the consumption of powdered coal, will cause such a demand for small coal as will leave these utilizing processes without material to work on.

Quatrefages on Human Crania.—Quatrefages is engaged on a work entitled "Crania of the Human Races," and recently laid before the Paris Academy of Sciences a synopsis of the results which he there proposes to establish. The materials he has at hand for this investigation are abundant—no less than 4,000 skulls; and he acknowledges the valuable assistance rendered to him by the most eminent *savants* both of France and of the rest of Europe. He holds that the fossil races are not extinct, but that, on the contrary, they have yet living representatives. He regards the skull discovered in 1700 at Canstadt, near Stuttgart, as the type of the most ancient human race of which we have any knowledge. This skull is dolichocephalous—that is, having a length greater than its breadth. With the Canstadt skull he classes those of Enghisheim, Brux, Neanderthal, La Denise, Staengenaes, Olmo, and Clichy—the last-named three being the skulls of females. Among the representatives, in historical times, of the dolichocephalous race, M. Quatrefages reckons Kay Lykke, a Danish statesman of the seventeenth century, whose skull is portrayed in the forthcoming work; Saint Mansuy, Bishop of Toul in the fourth century, whose skull is also figured; and Robert Bruce. Whether the cranium is long or short—dolichocephalous or brachycephalous—is a question which has nothing to do with the intellectual status of the man, according to M. Quatrefages.

Heart-Disease and Overwork.—The early break-down of health observed among Cornish miners, and commonly regarded as an affection of the lungs—"miners' phthisis"—is declared, by competent authority, to proceed rather from disturbed action of the heart; and this, according to Dr. Houghton, the distinguished Dublin physiologist, is caused by the great and sudden strain put upon the system by the ascent from the pits, at a time when the body is not sufficiently fortified with food. In his valuable address on the "Relation of Food to Work," Dr. Houghton says: "The labor of the miner is peculiar, and his food appears to me badly suited to meet its requirements. At the close of a hard day's toil the weary miner has to climb, by vertical ladders, through a height of from 600 to

1,200 feet, before he can reach his cottage, where he naturally looks for his food and sleep. This climbing of the ladders is performed hastily, almost as a gymnastic feat, and throws a heavy strain (amounting to from one-eighth to one-quarter of the whole day's work) upon the muscles of the tired miner, during the half-hour or hour that concludes his daily toil. A flesh-fed man (as a red Indian) would run up the ladders like a cat, using the stores of force already in reserve in his blood; but the Cornish miner, who is fed chiefly upon dough and fat, finds himself greatly distressed by the climbing of the ladders—more so, indeed, than by the slower labor of quarrying in the mine. His heart, over-stimulated by the rapid exertion of muscular work, beats more and more quickly in its efforts to oxidate the blood in the lungs, and so supply the force required. Local congestion of the lung itself frequently follows, and lays the foundation for the affection so graphically though sadly described by the miner at forty years of age, who tells you that his other works are very good, but that he is 'beginning to leak in the valves' Were I a Cornish miner, and able to afford the luxury, I should train myself for the 'ladder-feat' by dining on half a pound of rare beefsteak and a glass of ale from one to two hours before commencing the ascent."

Poisonous Volcanic Gases.—During a volcanic eruption on the little island of San Jorge, one of the Azores, in the year 1808, vaporous clouds were seen to roll down the sides of the mountain, and to move along the valley. Wherever they passed, plants and animals wilted and perished instantaneously. From this asphyxiating action, as also from their downward movement on the mountain-side and toward the sea, we may conclude that they consisted chiefly of some dense, deleterious gas, most probably carbonic acid. Their opacity is to be attributed to the presence of watery vapor, and their reddish color to the presence of fine volcanic dust. Finally, their injurious action on plants was doubtless owing to the presence of chlorhydric and sulphurous acid. Similar phenomena have been observed on occasion of other volcanic outbreaks, but nowhere so marked as in the case of San Jorge. In 1866, for instance, the volcano of Santorin emitted smoke charged with acid, which produced on plants effects similar to those observed at San Jorge in 1808.

A writer in the *Revue Scientifique* is of the opinion that the facts above stated give the solution of some of the problems raised by the exhumations at Pompeii. The strange posture of skeletons found in the streets of that town is very difficult to account for, if we insist on finding analogies with phenomena observed in modern eruptions of Vesuvius. A shower of ashes, however heavy, however charged with humidity, could never have thrown down and choked a strong man like the one who met his death while making his escape, in company with his two daughters, along one of the public roads. They must have inhaled a poisonous gas of some kind, which caused them to perish in fearful agony. This gas would not lie in a layer of equal thickness: in some places it might have a greater depth than in others. Hence, while some of the inhabitants would perish, the remainder would escape.

It is very probable that the eruption in the year 79 was accompanied with local emissions of carbonic acid, springing from points remote from the crater. In all volcanic regions, says the author, there are localities where, even when the volcano is inactive, carbonic acid exists in the atmosphere, in quantities sufficient to produce asphyxia: and the neighborhood of Vesuvius is particularly noted for the number of such localities. During an eruption, the amount of the gas given out is usually increased, and wells, ditches, quarries, etc., are filled with carbonic acid. It is sometimes dangerous to enter cavities in the rocks on the coast when a fresh breeze does not keep them free of the poisonous gas. In 1861 Ste.-Claire Deville came near meeting his death by entering one of these cavities for a few moments. The following week he and the author barely escaped being asphyxiated in the bed of a great quarry, which they had previously visited many a time with impunity.

A Relic of Ancient Etrurian Art.—An antiquarian discovery of very considerable interest was recently made at Cervetri, Italy, being a terra-cotta sarcophagus of native Etruscan production. The ancient Etrurians were noted for the honor they bestowed upon their dead, and their custom of paying homage to ancestors by placing their effigies upon their tombs seems to have been peculiar to themselves, and unknown among the Greeks. The recently-discovered sarcophagus is now in the British Museum. It measures internally four feet ten inches in length, and two feet in width. The floor is hollowed out, or rather marked by a raised border, which takes the form of a human figure. It rests upon four claw feet projecting beyond the angles, and terminating above in the head and breasts of a winged siren. The lid of the sarcophagus represents an upholstered couch upon which recline two human figures, male and female. There are inscriptions on the four sides of the couch. The panel at the foot has the figures of two warriors in panoply, and the front panel exhibits the same pair of warriors engaged in mortal combat. Several accessory figures are also to be seen. On the panel at the head of the couch are represented four sitting figures in opposing pairs, plunged in deep sorrow. The monument has no counterpart among those of its kind hitherto discovered, the only one at all resembling it being that of the Campana Collection in the Louvre. The latter is, however, of a much more recent date than the former, nor is it adorned with either reliefs or inscriptions. The Cervetri sarcophagus probably dates from the period of Etruscan ascendency in Italy.

Audible and Inaudible Sounds.—The phenomenon of color-blindness is a familiar fact; but an analogous phenomenon, what might be called pitch-deafness, though not uncommon, is not so generally known. By *pitch-deafness* is meant insensibility to certain sound-vibrations. Prof. Donaldson, of the University of Edinburgh, used to illustrate the different grades of sensibility to sound by a very simple experiment, namely, by sounding a set of small organ-pipes of great acuteness of tone. The gravest note would be sounded first, and this would be heard by the entire class. Soon some one would remark, "There, 'tis silent," whereas all the rest, perhaps, would distinctly hear the shrill piping continued. As the tone rose, one after another of the students would lose sensation of the acute sounds, until finally they became inaudible to all.

There is reason for supposing that persons whose ear is sensitive to very acute sounds are least able to hear very grave notes, and *vice versa*. Probably the hearing capacity of the human ear ranges over no more than 12 octaves. The gravest note audible to the human ear is supposed to represent about 15 vibrations per second, and the sharpest 48,000 per second.

The auditory range of animals is doubtless very different from that of man; they hear sounds which are insensible to us, and *vice versa*. Many persons are insensible to the scream of the bat—it is too acute. But to the bat itself that sound must be in all cases perfectly sensible. If, then, we suppose the bat to have an auditory range of 12 octaves, and its scream or cry to stand midway in that range, the animal would hear tones some six octaves higher than those audible to the human ear—two and a half million vibrations per second.

Scoresby and other arctic voyagers and whale-hunters have observed that whales have some means of communicating with one another at great distances. It is probable that the animals bellow in a tone too grave for the human ear, but quite within the range of the cetacean ear.

The Motions of the Heart.—According to the generally-accepted teachings of physiologists, the heart rests after each pulsation; that is, each complete contraction during which the auricles are emptied into the ventricles, and the ventricles into the vessels, is followed by a moment's repose, when the organ is entirely at rest. Dr. J. Bell Pettigrew, in his recently-published lectures on the "Physiology of the Circulation," takes a different view, affirming that the normal action of the heart is a continuous one, and that as a whole it never ceases to act until it comes to a final stop. He says: "When the heart is beating normally, one or other part of it is always moving. When the veins cease to close, and the auricles to open, the auricles begin to close and the ventricles to open; and so on in endless succession. In order to admit of these changes, the auriculo-ventricular valves, as has been stated, rise and fall like the diaphragm in respiration; the valves protruding, now into the auricular cavities, now into the ventricular ones. There is in reality no pause in the heart's action. The one movement glides into the other as a snake glides into the grass. All that the eye can detect is a quickening of the gliding movements, at stated and very short intervals. A careful examination of the sounds of the heart shows that the sounds, like the movements, glide into each other. There is no actual cessation of sound when the heart is in action. There are periods when the sounds are very faint, and when only a sharp or an educated ear can detect them, and there are other periods when the sounds are so distinct that even a dull person must hear; but the sounds—and this is the point to be attended to—merge into each other by slow or sudden transitions. It would be more accurate, when speaking of the movements and sounds of the heart, to say they are only faintly indicated at one time, and strongly emphasized at another, but that neither ever altogether ceases. If, however, the heart is acting more or less vigorously as a whole, the question which naturally presents itself is, How is the heart rested? There can be little doubt it rests, as it acts, viz., in parts. The centripetal and centrifugal wave-movements pass through the sarcous elements of the different portions of the heart very much as the wind passes through the leaves: its particles are stirred in rapid succession, but never at exactly the same instant; the heart is moving as a whole, but its particles are only moving at regular and stated intervals; the periods of repose, there is every reason to believe, greatly exceeding the periods of activity. The nourishment, life, and movements of the heart are, in this sense, synonymous."

Poisoning by Oxygen.—M. Paul Bert, whose observations upon the physiological effects of high atmospheric pressure we have already noted in the MONTHLY, communicates to the Paris Academy of Sciences the results of his observations on the toxic action of oxygen. Placing sparrows in oxygen under a pressure of 350 (that of the atmosphere being represented as 100), he found the birds seized with violent convulsions. The same result followed when sparrows were confined in common air under a pressure of 17 atmospheres. In oxygen, at 3½ atmospheres' pressure, or in air at 22 atmospheres, the convulsions were extremely violent and quickly fatal. The symptoms in the latter case were these: Convulsions set in after four or five minutes: in moving about, the bird hobbles on its feet, as though walking on hot coals. It then flutters its wings, falls on its back, and spins about, the claws doubled up. Death supervenes after a few such spasms.

The toxic dose of oxygen for a dog was found to require, for convulsions, a pressure of 350 in oxygen; and a pressure of 500 is fatal. The amount of oxygen in the arterial blood of a dog in convulsions was found to be considerably less than twice the normal quantity. Hence the author's startling conclusion, that *oxygen is the most fearful poison known.*

Taking a dog in full convulsion out of the receiver, M. Bert found the paws rigid, the body bent backward in the shape of an arch, the eyes protruding, pupil dilated, jaws clinched. Soon there is relaxation, followed by another crisis, combining the symptoms of strychnine-poisoning and of lockjaw. The convulsionary periods, at first recurring every five or six minutes, become gradually less violent and less frequent.

The author sums up his conclusions as follows: 1. Oxygen behaves like a rapidly-fatal poison, when its amount in the arterial blood is about 35 cubic centimetres per cent. of the liquid; 2. The poisoning is characterized by convulsions which represent, according to the intensity of the symptoms, the various types of tetanus, epilepsy, poisoning by phrenic acid and strychnine, etc.; 3. These symptoms, which are allayed by chloroform, are due to an exaggeration of the excito-motor power of the spinal cord; 4. They are accompanied by a considerable and constant diminution of the internal temperature of the animal.

Infant Mortality.—During the year 1868, 23,198 children under one year of age, died by convulsions in England, the number of births being 786,858—one in 34. In the same year the births in Scotland were 115,514, and only 312 infants under one year—one in 370—fell victims to convulsions. This striking difference in the mortality statistics of the two countries is accounted for in a report of the Scottish Registrar-General by the difference between the English and the Scottish modes of rearing infants. "The English," he writes, "are in the habit of stuffing their babies with spoon-meat almost from birth, while the Scotch, excepting in cases where the mother is delicate, or the child is out nursing, wisely give nothing but the mother's milk till the child begins to cut its teeth." The statistics of infantile deaths from diarrhœa may also be adduced as an argument in favor of the Scottish system. In England more than twice as many infants die of this disorder than in Scotland.

On comparing these statistics with those of the last United States census, it will be seen that the chances of life for infants in their first year are far more favorable in this country than in England, though not so favorable as in Scotland. In the year ending May 31, 1870, there were born in the United States 1,100,475 children. Of these there died, during the same year 4,863 by convulsions, and 1,534 by diarrhœa, or one in 236 from the former cause, and one in 724 from the latter. In England the deaths from diarrhœa amounted to 138 in 100,000 infants, and in Scotland to 66 in the same number. It will be seen, on computation, that the proportion of deaths from this cause are by a very small fraction less in the United States than in Scotland. But now are we to attribute these very creditable results to our more rational system of rearing children, or to the better social condition of the population here?

Snakes swallowing their Young.—The question, "Do snakes swallow their young?" that is, give them shelter in the maternal stomach when danger threatens, was discussed in a paper presented to the American Association by G. Brown Goode. The author some time since asked, through the public press, for testimony bearing on this subject, and he now comes forward with what appears to be perfectly satisfactory evidence in favor of the affirmative side. He has the testimony of fifty-six witnesses who saw the young enter the parent's mouth. Of these fifty-six, nineteen testify that they heard the parent snake warning her young of danger by a loud whistle. Two of the witnesses waited to see the young emerge again from their refuge, after the danger was past; and one of them went again and again to the snake's haunt, observing the same act on several successive days. Four saw the young rush out when the parent was struck; eighteen saw the young shaken out by dogs, or escaping from the mouth of their dead parent. These testimonies are confirmed by the observations of scientific men, such as Prof. Smith, of Yale College, Dr. Palmer, of the Smithsonian Institution, and others.

NOTES.

The year 1759, which witnessed the completion of the Eddystone Lighthouse, closed with tremendous storms, and the courage of the light-keepers was tested to the utmost. A biography of John Smeaton, the builder of the Eddystone, states that for twelve days the sea ran over them so much that they could not open the door of the lantern, or any other door. "The house did shake," said one of the keepers, "as if we had been up a great tree. The old men were frightened out of their lives, wishing they had never seen the place. The fear seized them in the back, but rubbing them with oil of turpentine gave them relief!"

Sir Charles Lyell, in his "Geology," speaking of Madagascar, says that, with two or three small islands in its immediate vicinity, it forms a zoological sub-province, in which all the species except one, and nearly all the genera, are peculiar. He singles out for special remark the lemurs of Madagascar, comprising seven genera, only one of which has any representatives on the nearest main-land of Africa. Hitherto no fossil remains of these Madagascar species have been known to exist, but M. Delfortrie, of the French Academy of Sciences, announces that he has found, in the phosphorite of the department of Lot, an almost complete skull of an individual belonging to this lemurine family.

Of the 35,170,294 passengers carried over the railroads of Pennsylvania last year, only thirty-three were killed, less than one in a million. But the English lines make a far more favorable showing, the number killed in the year 1871 being only twelve—or one in 31,000,000.

In the "History of the Fishes of the British Islands," Giraldus Cambrensis, a writer of the twelfth century, is quoted for the observation that in the Lyn y Cwn, or Pool of Dogs, in Wales, the trout, the perch, and the eel, were deficient of the left eye. A recent work on "Trout and Salmon Fishing in Wales," strangely enough, confirms in part this observation, asserting that one-eyed trout are still caught in the same waters.

Professor Smee recently, at the Berlin Chemical Society, proposed a method for detecting organic matters contained in the air, and for effecting at the same time a kind of distillation by cold. A glass funnel, closed at its narrow end, is held suspended in the air and filled with ice. The moisture of the air is condensed, in contact with the exterior surface; it trickles to the bottom of the apparatus, and falls into a small basin placed for its reception. The liquid obtained in a given time is weighed. It generally contains ammonia, which is determined by known methods. Distillation by cold may be employed for separating volatile substances which might be injured by heat. Thus, if flowers are placed under a large bell-glass along with the refrigerating funnel, a liquid is obtained in the basin saturated with the odorous principles of the flowers.

At various points on the river Thames, between Woolwich and Erith, there are visible at low water the remains of a submerged forest, over which the river now flows. This fact, taken in connection with other local phenomena, has led geologists to conclude that the present outlet of the Thames to the North Sea is of quite recent origin, the waters having formerly passed southward into the Weald by channels which still remain. Excavations in the marshes expose to view a deep stratum of twigs, leaves, seed-vessels, and stools of trees, chiefly of the yew, alder, and oak kinds.

A traveller in Zanzibar describes the red and black ants as one of the greatest scourges with which Eastern Africa is afflicted. These insects, he says, move along the roads in masses so dense that beasts of burden refuse to step among them. If the traveller should fail to see them coming, in time to make his escape, he soon finds them swarming about his person. Sometimes, too, they ascend the trees and drop upon the wayfarer. The natives call them *madinodo*, that is, boiling water, to signify the scalding sensation produced by their bite. These ants are of great size, and burrow so deep into the flesh that it is not easy to pick them out. In certain forests they are said to exist in such numbers as to be able to destroy rats and lizards.

An eccentric and methodical man is Dr. Rudolf, Danish governor of Upernavik, Greenland. Dr. Rudolf is a scientist of some distinction, and has contributed his share to the scientific literature of his own country, yet it is his choice to live in a region where darkness prevails four months in the year, and where he can have no communication with civilized life beyond the annual visit from the government storeship, and the casual arrival of whalers. By the storeship the governor receives annually a file of Danish newspapers; but instead of glancing through them hastily, he takes a fresh journal every morning, reading the *Dagblad* of Jan. 1, 1872, on Jan. 1, 1873. He thus follows, day for day, the changes in the mind of Denmark: is glad in the order in which Copenhagen is glad, and *vice versa*, but always precisely twelve months after the event.

If the white of an egg be immersed for some 12 hours in cold water, it undergoes a chemico-molecular change, becoming solid and insoluble. The hitherto transparent albumen assumes an opaque and snow-white appearance, far surpassing that of the ordinary egg. Dr. John Goodman, writing in the *Chemical News*, recommends this material for diet in cases where a patient's blood lacks fibrine. The substance being light and easily digested, it is not rejected even by a feeble stomach; and as it creates a feeling of want rather than of repletion, it promotes, rather than decreases, the appetite for food. After the fibrine has been produced in the manner described above, it must be submitted to the action of a boiling heat, and is then ready for use.

One of the great dangers attending the use of the various sedatives employed in the nursery is that they tend to produce the *opium-habit*. These quack medicines owe their soothing and quieting effects to the action of opium, and the infant is by them given a morbid appetite for narcotic stimulants. The offering for sale of such nostrums should be prohibited, as tending to the physical and moral deterioration of the race. In India mothers give to their infants sugar-pills containing opium, and the result is a languid, sensual race of hopeless debauchees. In the United States the poisonous dose is administered under another name; but the consequences will probably be the same.

During last autumn, says the *Journal of the Society of Arts*, there were no less than seventeen companies engaged in extracting gold from the auriferous sand of Finland. The alluvial deposits at Toalo are said to be extremely rich in gold, the total production last season being estimated at about $50,000. One of the companies returned a dividend of 70 per cent. The largest nugget weighed 40 grammes.

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