THE

SCIENCE OF COMMON THINGS;

A

FAMILIAR EXPLANATION

OF THE

FIRST PRINCIPLES OF PHYSICAL SCIENCE.

FOR

SCHOOLS, FAMILIES, AND YOUNG STUDENTS.

Illustrated with numerous Engravings.

BY

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PREFACE.

The design of the present volume is to furnish for the use of schools and young persons, an elementary text-book on the first principles of science. For this purpose, the system of question and answer, which for certain classes of pupils and for familiar instruction has proved eminently popular, has been followed. The advantages of this system are :—first, that it affords a most simple and easy method of communicating useful and practical information :—second, the question excites a feeling of curiosity in the mind of the young student, which serves to fix the subject-matter more strongly in the memory :—and thirdly, the form of question and answer imparts truth to the mind, in a logical sequence of cause and effect, and by showing how consequents in sciences are deduced from antecedents, unconsciously trains and familiarizes the pupil to think and reason according to the true spirit of inductive philosophy.

It is believed that the questions in the present volume are simple, practical, and expressed in the plainest language that the subject allows. Engravings have also been used to illustrate more clearly the most important topics treated of.

As this work has been designed exclusively as an elementary book, the more abstruse and difficult departments of physical science have been passed over, or briefly noticed; such as the theory and application of the mechanical powers, the polarization of light, crystallography, &c. Those who are desirous of possessing a more complete and elaborate work, arranged in the form of question and answer,—embracing the whole subjects of Natural Philosophy, Organic and Inorganic Chemistry, the applications of science to the Industrial Arts, Geology, &c., are referred to a work by the author of the present volume, entitled "Wells's Familiar Science" and to "Wells's Natural Philosophy," in both of which special reference is made to the application of the principles of physical science to the useful arts and necessities of every-day life.

In the preparation of the "Science of Common Things" especial care has been taken to render the facts and principles given, full, complete, and accurate, and in strict conformity with the very latest results and researches of modern science.

NEW YORK, May, 1857.

SCIENCE OF COMMON THINGS.

PART I.

LAWS AND PROPERTIES OF MATTER.

CHAPTER I.

WHAT WE KNOW OF MATTER, AND HOW WE KNOW IT.

1 *What is matter?*

We apply the term matter to any substance which affects our senses.

2 *How do we know that anything exists?*

Because our *senses* give us evidence of the fact.

3 *What are the senses?*

They are the instruments, or means, by which the mind is enabled to know that matter exists and possesses certain properties.

4 *How many senses are there?*

Five; hearing, seeing, smelling, tasting, and feeling.

5 *Would a person deprived of all sensation, be conscious of any material existence?*

He would not; for all knowledge of the material world is derived through the medium of the *senses.*

6 *Is the impression transmitted to the mind by each organ of sensation, different?*

It is; each organ of sense is adapted to receive a particular influence of matter; and is designed to convey to the mind immediate notice of some peculiar action. This is the more noticeable, when we consider that, however delicate its structure, each organ of sense is wholly insensible to every influence except that to which it is especially adapted; thus, the eye is never affected by *sound*, nor the ear by *light*.

7 *What is meant by the term body?*

Any distinct portion of *matter* existing in, and occupying space.

8 *What do we mean, when we speak of the properties or qualities of a body?*

The *powers* belonging to the body, which are capable of exciting in our mind certain sensations.

9 *What are the general properties of matter?*

The principal qualities of matter are MAGNITUDE or EXTENSION, IMPENETRABILITY, DIVISIBILITY, POROSITY, INERTIA, DENSITY, ELASTICITY, DUCTILITY, and MALLEABILITY.

10 *What is magnitude?*

The property of occupying *space*. It is impossible to conceive of a portion of matter so minute as to have no magnitude.

11 *What do we mean by the term size of a body?*

The quantity of *space* a body occupies.

12 *What is the surface of a body?*

The *external limits* of its magnitude.

13 *What is the area of a body?*

The quantity of *surface*.

14 *What is impenetrability?*

That quality of matter which precludes the possibility of two bodies occupying the *same space at the same time*. When bodies are said to be impenetrable, it is therefore meant, that one cannot pass through another without displacing some, or all, of the component parts of that other.

There are many instances of apparent penetration; but in all these, the parts of the body which seem to be penetrated are only displaced. Thus, if a needle be plunged into a vessel of water, all the water which previously filled the space into which the needle enters, will be displaced; and the level of the water will rise in the vessel to the same height as it would by pouring in so much more water as would fill the space occupied by the needle.

15 *Why will water, or any other liquid, poured into a funnel, closely inserted in the mouth of a bottle, or decanter, run over the sides?*

Because the air filling the bottle, and having no means of escape, prevents the fluid from entering the bottle; but if the funnel be lifted from the neck of the bottle a little, so as to afford the air an opportunity to escape, the water will then flow into the bottle in an uninterrupted stream.

16 *What is the figure of a body?*

Its *form* or *shape*, as expressed by its boundaries or terminating extremities.

17 *What is meant by the divisibility of matter?*

Its property, or capability of being divided.

18 *Is matter capable of being divided into separate portions infinitely or without limit?*

So far as we are able to perceive with our senses, all matter is capable of being divided into separate portions without limit; yet the recent investigations of chemistry have proved beyond a doubt, that there is a point beyond which matter is no longer divisible. Such a portion of matter as cannot be divided we call an atom.

19 *What then is an atom of matter?*

A *particle* so minute, as to admit of no division. Atoms are conceived to be the first principles or component parts of all bodies.

The extent to which matter can be divided and yet be perceived by the senses, is wonderful.

An ounce of gold may be divided into four hundred and thirty-two thousand million parts. Each of these parts will retain all the characters and qualities which are found in the largest masses of metal. It retains its solidity, texture, and color; it resists the same agents, and enters into combination with the same substances.

20 *What is a particle of matter?*

The term particle is also used to express *small component parts* of matter, but is generally applied to those which are *not too minute* to be discovered by observation.

21 *What are the pores of a body?*

No two particles of matter are supposed to be in actual contact with each other; and the openings, or interstitial spaces between these particles, are called *pores.*

22 *What is the reason that a sponge, a piece of wood or metal, can, by pressure, be made to occupy a smaller space than it did originally?*

Because the particles of which the sponge, the piece of wood or metal, are composed, are by pressure brought more closely together, diminishing at the same time the pores and the space the body occupies.

23 *What then is compressibility?*

That quality of matter in virtue of which a body allows its volume or size to be *diminished*, without diminishing the number of atoms or material particles of which it consists.

24 *What reason have we for supposing that no two particles of matter are in absolute contact?*

Because all known bodies, whatever may be their nature, are capable of having their dimensions reduced without diminishing the amount of matter contained in them; hence the space by which the volume may be diminished must, before diminution, consist of *pores.*

25 *What is density?*

The proportion of the quantity of matter in a body to its magnitude. Thus, if of two substances one contains in a given space twice as much matter as the other, it is said to be *twice as dense.*

26 *What connexion is there between the density of a body and its porosity?*

A body will be more or less dense according as its particles are near to or remote from each other; and hence it is evident that the *greater* the density the *less* the porosity, and the *greater* the porosity the *less* the density.

27 *Why do we call lead heavy, and feathers light?*

Because the amount of matter contained in a quantity of lead occupying a given space is much greater than in a quantity of feathers capable of occupying the much more dense than the diamond, yet the metal is soft, while the diamond is the hardest body in nature.

56 *When is a body said to be ductile?*

When it is capable of being *drawn into wire.* In ductile substances the atoms seem to have no more fixed relation of position than in a liquid, but yet they cohere very strongly.

57 *When is a body said to be malleable?*

When it is capable of being hammered or rolled into thin plates. Bodies that are malleable are not always ductile. Lead and tin may be hammered out into very thin plates, but it is difficult, or impossible, to draw out these metals into fine wire.

CHAPTER II.

ATTRACTION.

58 *What is attraction?*

It is the force manifested by the mutual *approach* or *cohesion* of bodies.

59 *Is all matter subject to the power of attraction?*

All matter is under the influence of attraction in some of its forms. Every particle of matter attracts every other particle, and is in turn itself attracted.

60 *What is repulsion?*

It is the force manifest in the movement of bodies from each other. Thus, if a piece of glass, having been briskly rubbed with a silk handkerchief, touch successively two feathers, these feathers, if brought together, will move asunder.

61 *What is cohesive attraction?*

It is the force which *holds together* the atoms of bodies. Cohesion acts only between particles of matter of the same kind, and at distances which are not measurable, or, as they are termed, *insensible distances.*

62 *What is adhesion?*

Adhesion is attraction between particles of matter of different kinds acting at immeasurably small distances only, and uniting the dissimilar particles into one mass.

63 *Why is mortar used to fasten bricks together?*

Because the adhesive attraction between the particles of the brick and the particles of mortar is so strong, that they unite to form one solid mass.

64 *Why is a bar of iron stronger than a bar of wood of the same size?*

Because the cohesion existing between the particles of iron is *greater* than that existing between the particles of wood.

65 *Why are the particles of a liquid more easily separated than those of a solid?*

Because the cohesive attraction which binds together the particles of a liquid is much less strong than that which binds together the particles of a solid.

66 *Why will a small needle, carefully laid upon the surface of water, float?*

Because its weight is not sufficient to overcome the cohesion of the particles of water constituting the surface; consequently, it cannot pass through them and sink.

67 *If you drop water and laudanum from the same vessel, why will sixty drops of the water fill the same measure as one hundred drops of laudanum?*

The cohesion between the particles of the two liquids is different, being greatest in the water. Consequently, the number of particles which will adhere together to constitute a drop of water is greater than in the drop of laudanum.

68 *Why is the prescription of medicine by drops an unsafe method?*

Because not only do drops of fluid from the same vessel, and often of the same fluid from different vessels, differ in size, but also drops of the same fluid, to the extent of a third, from different parts of the lip of the same vessel.

69 *Why is it difficult to pour water from a vessel which has not a projecting lip?*

Because, in consequence of the attraction between the water and the sides of the vessel, the fluid has a tendency to run down along the inclined outside of the vessel, and not at once to fall perpendicularly.

70 *What is the attraction of gravitation?*

We apply the term "gravity," or the "attraction of gravitation," to that tendency which every particle of matter in the universe has to approach all other matter. *Terrestrial gravitation* is the attraction of a body towards the centre of the earth.

71 *In what respect does the attraction of gravitation differ from all other attractive forces?*

Because it is the *common property of all bodies;* since everything to which we can attach the idea of materiality is affected more or less by gravitation.

72 *Why does an apple loosened from the tree fall to the ground?*

Because the *earth attracts* or *draws it* to itself.

73 *Since all bodies are attracted towards the earth, how does it happen that all smoke and some other forms of matter display the contrary phenomenon of ascending from it?*

Because the *smoke is lighter than the air*, *bulk for bulk*, and floats upon it. It is unable to advance, however, in the most minute degree, without displacing or thrusting downward portions of the atmosphere equal to its own bulk.

74 *Why does a cork pressed beneath the water rise and float on the surface?*

Because the *cork is lighter than an equal bulk of water*, and is pressed up and sustained by it in the same manner that the particles of smoke are sustained by the particles of air.

75 *Why does a balloon rise in the air?*

Because it is filled with a *gas* which is lighter, bulk for bulk, than the air.

76 *How long will smoke continue to float above the surface of the earth?*

Until its *particles*, *uniting*, *become heavier than the air*, when they descend in the form of small flakes of *soot*.

77 *Why do bubbles in a cup of tea range round the sides of the cup?*

Because the cup *attracts them.*

78 *Why do all the little bubbles tend towards the large ones?*

Because the large bubbles (being the superior masses) *attract them.*

79 *Why do the bubbles of a cup of tea follow a tea-spoon?*

Because the tea-spoon *attracts them.*

80 *Do all bodies attract each other equally?*

They attract each other with forces proportioned to their *masses.*

81 *A feather falls to the ground by the influence of the earth's attraction. Now, as all bodies attract each other, does the feather attract or draw up the earth in any degree towards itself?*

It does, with a force proportioned to its mass; but as the mass of the earth is infinitely greater than the feather, the influence of the feather is infinitely small, and we are unable to perceive it.

82 *What would be the consequence if the feather did not attract the earth?*

If *any portion* of the earth, however small, *failed* to attract another portion, and not be itself attracted, the *axis of the earth would be immediately changed*, involving an alteration of climate, and the place of the ocean in its bed.

83 *Why is it more dangerous to fall from a lofty elevation than from a low one?*

As the attraction of the earth varies inversely with the square of the distance, the *force* with which a falling body will strike the ground will increase in proportion to the height from which it has fallen.

84 *In what direction does a body, when not supported, endeavor to fall?*

In a line drawn from its centre of gravity towards the centre of the earth.

85 *Is the attraction of the earth the same at all distances from its surface or centre?*

No; the attraction of the earth for a body varies *inversely with the square of its distance from the centre.*

86 *How can this be illustrated?*

In the following manner:—If one body attracts another with a certain force at the distance of *one mile*, it will attract with *four times the force at half a mile*, *nine times the force at one-third of a mile*, and so on in like proportion. On the contrary, it will attract with but *one-fourth of the force at two miles*, *one-ninth of the force at three miles*, *one-sixteenth of the force at four miles*, and so on as the distance increases.

87 *What do we mean by the centre of gravity?*

That *point* in a body about which, if supported, the whole body will balance itself.

88 *When you balance a rod, a stick, or any other body, upon the finger, where is the centre of gravity of the stick or body?*

It is the point upon which the body will remain at rest, or upon which it is balanced.

89 *In what position only can a body rest?*

Only when its *centre of gravity* is supported; and until this is accomplished the body will move, and continue to do so, until it settles into a position in which the centre of gravity cannot sink lower.

90 *Why does a person carrying a weight upon his back stoop forward?*

In order to bring the centre of gravity of his body and the load over his feet.

Fig. 1.

Fig. 2.

If he carried the load in the position of A, *Fig.* 1, he would fall backwards, as the direction of the centre of gravity would fall beyond his heels; to bring the centre of gravity over his feet, he assumes the position indicated by B, *Fig.* 2.

91 *When a person carries a load upon his head, why is it necessary to stand perfectly upright?*

In order that the centre of gravity may be over his feet.

92 *Why does a person in rising from a chair bend forward?*

When a person is sitting, the centre of gravity is supported by the *seat;* in an erect position, the centre of gravity is supported by the *feet;* therefore, before rising it is necessary to change the centre of gravity, and by bending forward we transfer it from the chair to a point over the feet.

93 *Why does a quadruped, in walking, never raise both feet on the same side simultaneously?*

Because, if it did, the centre of gravity would be unsupported, and the animal would tend to fall over.

94 *Why is a large turtle placed on its back unable to move?*

Because the centre of gravity of the turtle is, *in this position*, *at the lowest point*, and the animal is unable to change it; therefore it is obliged to remain at rest.

95 *Why is it more difficult to overthrow a body having a broad base than one resting upon a narrow basis?*

Because a body cannot fall over, so long as a line directed from the centre of gravity vertically towards the surface upon which the body rests, falls within the figure formed by the base of the body in question.

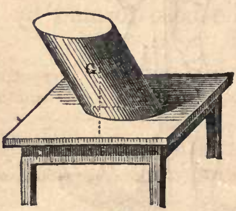


Fig. 3.

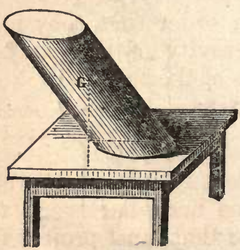


Fig. 4.

Hence, the *broader the base of a body, the more securely it will stand.*

Thus, in *Fig.* 3, the line directed vertically from the centre of gravity, G, falls within the base of the body, and it remains standing; but in *Fig.* 4 a similar line falls without the base, and the body consequently cannot be maintained in an upright position, and must fall.

96 *How long will a wall or tower stand securely?*

So long as the perpendicular line drawn through its centre of gravity falls within its base.

The celebrated leaning tower of Pisa, 315 feet high, which inclines 12 feet from a perfectly upright position, is an example of this principle. For instance, the line in *Fig.* 5, falling from the top of the tower to the ground, and passing through the centre of gravity, falls within the base, and the tower stands securely. If, however, an attempt had been made to build the tower a little higher, so that the perpendicular line passing through the centre of gravity would have fallen beyond the base, the structure could no longer have supported itself.

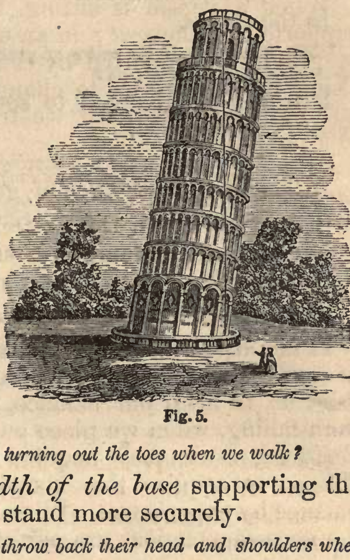


Fig. 5.

97 *What is the advantage of turning out the toes when we walk?*

It increases the *breadth of the base* supporting the body, and enables us to stand more securely.

98 *Why do very fat people throw back their head and shoulders when they walk?*

In order that they may effectually keep the centre of gravity of the body over the base formed by the soles of the feet.

99 *Why cannot a man, standing with his heels close to a perpendicular wall, bend over sufficiently to pick up any object that lies before him on the ground, without falling?*

Because the wall prevents him from throwing part of his body backward, *to counterbalance the head and arms* that must project forward.

100 *What is the reason that persons walking arm-in-arm shake and jostle each other, unless they make the movements of their feet to correspond, as soldiers do in marching?*

When we walk at a moderate rate, the centre of gravity comes alternately over the right and over the left foot. The body advances, therefore, in a *waving line;* and unless two persons walking together keep step, the waving motion of the two fails to coincide.

101 *Where would the centre of gravity be in a wheel made entirely of wood and of a uniform thickness?*

In the *centre.*

102 *Where would the centre of gravity be if a part of the rim of the same wheel were made of iron?*

It would be changed to some point *aside* from the centre of the wheel.

103 *In what does the art of balancing or walking upon a rope consist?*

In keeping the centre of gravity in a line over the base upon which the body rests.

104 *What is the base upon which the human body rests or is supported?*

The *two feet* and the *space* included between them.

105 *Why is it a very difficult thing for children to learn to walk?*

In consequence of the natural upright position of the human body, it is constantly necessary to employ some exertion to keep our balance, or to prevent ourselves from falling, when we place one foot before the other. Children, after they acquire strength to stand, are obliged to acquire this knowledge of preserving the balance by experience. When the art is once acquired, the necessary actions are performed involuntarily.

106 *Why do young quadrupeds learn to walk much sooner than children?*

Because a body is tottering in proportion to its great *altitude* and *narrow base.* A child has a body thus constituted, and learns to walk but slowly because of this difficulty, (perhaps in ten or twelve months,) while the young of quadrupeds, having a *broad supporting base,* are able to stand and move about almost immediately.

107 *Are all the limbs of a tall tree arranged in such a manner, that the*

line directed from the centre of gravity is caused to fall within the base of the tree?

Nature causes the various limbs to shoot out and grow from the sides with as much exactness, in respect to keeping the centre of gravity within the base, as though they had been all arranged artificially. Each limb grows, in respect to all the others, in such a manner as to preserve a due balance between the whole.

CHAPTER III.

WEIGHT.

108 *What is weight?*

Weight is the measure of the attraction of gravitation, or, in other words, it is the *measure of force* with which a body is attracted by the earth. In an ordinary sense *it is the quantity of matter contained in a body, as ascertained by the balance.*

109 *To what is the weight of a body proportional?*

The *weight of a body* is always proportional to the *quantity of matter* contained in it.

110 *Why will a ball of lead weigh more than a ball of cotton of the same size?*

Because the quantity of matter contained in the ball of lead is much greater than the quantity of matter contained in the ball of cotton. The attraction of gravitation being proportioned to the quantity of matter, it follows that the lead ball will be drawn towards the earth with a greater force (*i. e. will weigh more*) than the ball of cotton.

111 *A man of moderate weight upon the surface of the earth would weigh two tons if transported to the surface of the sun: why would he weigh more upon the surface of the sun than upon the surface of the earth?*

Because the attractive force of the sun, on account of its greater magnitude, far exceeds the attractive force of the earth.

112 *Why will a mass of iron weigh less on the top of a high mountain than at the level of the sea?*

Because the force of the earth's attraction is less at the top of the mountain than at the sea-level; the attraction (and, therefore, the weight of a body) being greatest at the surface of the earth, and decreasing upward, as the square of its distance from the centre of the earth increases.

A ball of iron, weighing a thousand pounds at the level of the sea, would be perceived to have lost two pounds of its weight if taken to the top of a mountain four miles high, a spring balance being used.

113 *Where will a body weigh the most on the surface of the earth?*

At the poles of the earth, for at these points the attractive power is greatest.

It must be remembered that the earth is not a perfect sphere, but flattened at the poles; consequently, the poles of the earth are nearer the centre of attraction (*i. e.* the centre of the earth) than any other point on its surface.

114 *Where will a body weigh the least on the earth's surface?*

At the *equator*, for there the attractive power is less; the surface at this point being the most distant from the centre of the earth.

115 *What would be the weight of a body carried to the centre of the earth?*

It would have no weight; for the attraction of gravitation acting equally in every direction, no effect would be produced; and the body would be fixed as if sustained by a number of magnetic points.

116 *What two systems of weights are employed in the United States and Great Britain?*

Troy weight and *avoirdupois* weight.

117 *What is Troy weight used for, and from whence does it derive its name?*

Troy weight is used for weighing gold and silver. It derives its name from the ancient designation of London, *Troy Novant*, or from *Troyes*, in France, where it was first adopted in Europe. It has existed in England from the time of Edward the Confessor.

118 *What is avoirdupois weight used for, and from whence does it derive its name?*

Avoirdupois weight is used for the weight of merchandise other than the precious metals. It derives its name from the French *avoirs* (*averia*), goods or chattels, and *poids*, weight.

119 *What is a grain weight?*

A *grain weight* is the smallest measure of weight made use of in the English system. By a law of England enacted in 1286, it was ordered that 32 grains of wheat, well dried, should weigh a pennyweight. Hence the name *grain* applied to this measure of weight. It was afterwards ordered that a pennyweight should be divided into only 24 grains.

120 *How do we make a grain weight for practical purposes?*

By weighing a thin plate of metal of uniform thickness, and cutting out, by measurement, such a proportion of the whole as should give one grain. In this way, weights may be obtained for chemical purposes, which weigh only $\frac{1}{1000}$th part of a grain.

121 *What part of an inch is a line?*

One-twelfth of an inch is designated as a line.

122 *Are the standards of weights and measures in the United States the same as in Great Britain?*

They are essentially the same.

123 *Where are the standards of weights and measures to be found in the United States?*

At *Washington*, and at the *capitals* of the several States of the Union; sets having been furnished to each State by the United States.

124 *Are the weights and measures used in France the same as those of the United States and England?*

No; they are entirely different. Within a comparatively recent time the French have reconstructed their old system of weights and measures, and formed another on an entirely new plan. The French system is, at present, the best and most accurate system existing.

CHAPTER IV.

MOTION.

125 *What is force?*

Force is whatever *causes* or *opposes* the production of motion in matter.

126 *What is motion?*

It is the term applied to the phenomena of the *changing of place among bodies.*

127 *What would be the state of things if no motion existed?*

The *universe* would be *dead.* There would be no rising and setting of the sun, no flow of water or of air (wind), no sound, light, or animal existence.

128 *The surface of the earth at the equator moves at the rate of about a thousand miles in an hour: why are men not sensible of this rapid movement of the earth?*

Because *all objects* about the observer *are moving in common* with him. It is the natural uniformity of the undisturbed motion which causes the earth and all the bodies moving together with it upon its surface to appear at rest.

129 *How can you easily see that the earth is in motion?*

By looking at some object that is entirely *unconnected* with it, as the *sun* or the *stars.* We are here, however, liable to the mistake that the sun or stars are in motion, and not we ourselves with the earth.

130 *Does the sun really rise and set each day?*

The sun maintains very nearly a constant position; but the earth revolves, and is constantly changing its position. *Really, therefore, the sun neither rises nor sets.*

131 *What do we mean by the term friction?*

In *mechanics,* it signifies the resistance which a moving body meets with from the surface on which it moves.

132 *Is it possible to construct any machine, or arrangement of matter, which will perpetually continue in motion?*

It is not; because the operations of *gravity*, the *resistance of the medium through which the body moves, or the friction of the surfaces upon which the body rests*, will, in a given time, destroy and terminate all motion. In addition to this, all materials which we employ in construction will, in the course of time, *wear out* by use, or *decay* by natural agencies.

133 *Do we know of any instances of perpetual motion in nature?*

Yes; the various *planetary bodies* belonging to the solar system have been moving with undiminished velocity for ages past; and, unless prevented by the agency which governs all nature, will continue to move in the same manner for ages to come.

134 *Why are horses obliged to make a much greater exertion to start a carriage than afterwards to keep it in motion?*

Because when a carriage is once put in motion upon a level road, with a determinate speed, the only force necessary to sustain the motion is that which is sufficient to *overcome the friction of the road;* but, at starting, a greater expenditure of force is necessary, inasmuch as not only the *friction* is to be overcome, but the *force with which the vehicle is intended to move* must be communicated to it.

135 *What is centrifugal force?*

It is that *force* which causes a revolving body *to fly from a centre.*

136 *Why does a stone, discharged from a sling, move forwards, when the cord which retained it is loosened?*

Because of the *centrifugal force* it has acquired by the whirling of the sling previous to the discharge.

137 *Why do grindstones or wheels, in rapid motion, not unfrequently break and fly to pieces with great violence?*

Because the *centrifugal force*, generated by the rapid revolving motion, overcomes the cohesion of the particles, and thus causes them to *separate and fly from the centre.*

138 *Can almost all revolving bodies be broken by sufficient rotative velocity?*

Yes; for the centrifugal force increases with the *rapidity of revolution*, and finally becomes too strong to be resisted by the *cohesive force* which binds the particles of the body together.

139 *When a vessel containing water is whirled rapidly round, why does not the water fall out when the vessel is upside down?*

Because the *centrifugal force*, tending to make the water fly from the centre, *overcomes or balances* the *attraction of gravitation*, which tends to cause the water to fall out.

In *Fig.* 6, the water contained in the bucket which is upside down, has no support under it, and if the bucket were kept still in its inverted position for a single moment the water would fall out by its own weight, or, in other words, by the attraction of gravitation; but the centrifugal force, which is caused by the whirling of the bucket in the direction of the arrow, tends to drive the water out through the bottom and side of the vessel, and as this last force is equal to and balances the other, the water retains its place, and not a drop is spilled.

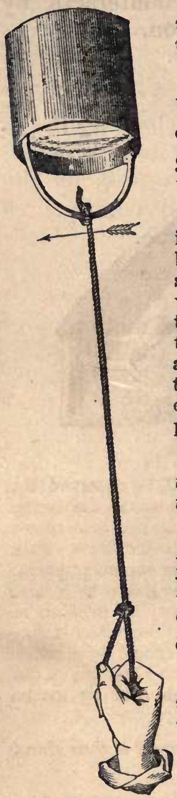


Fig. 6.

140 *How much faster would the earth be required to revolve in order to make the centrifugal force equal to the attraction of gravitation?*

Seventeen times faster, or in eighty-four minutes, instead of twenty-four hours: in this case all bodies at the equator of the earth would be destitute of weight.

141 *What would be the consequence if the earth revolved around its axis in less time than eighty-four minutes?*

Gravitation would be completely overpowered, and *all fluids* and *loose substances* would fly from the surface.

142 *Why does a man or horse, in turning a corner rapidly, incline inwards, or lean towards the corner?*

Because the *centrifugal force*, produced by turning rapidly, tends to *throw him away from the corner;* therefore, he *inclines inwards* to counteract it.

143 *Why does a horse in a circus ring lean towards the centre?*

When the horse moves rapidly around the circular course, the centrifugal force generated, tends to throw him over, outwardly, or away from the centre of the ring; and this tendency the animal counteracts, by inclining his body in an opposite direction.

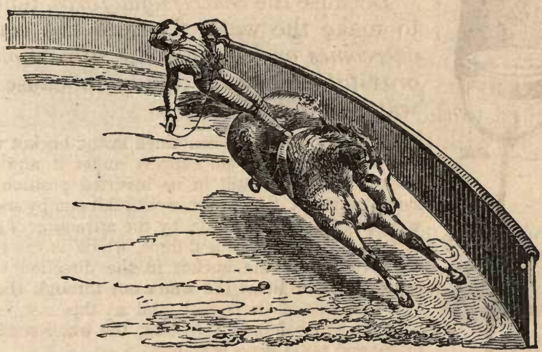


Fig. 7.

In all equestrian feats exhibited in the circus, it will be observed that not only the horse but the rider inclines his body towards the centre, *Fig.* 7, and according as the speed of the horse round the ring is increased, this inclination becomes more considerable. When the horse walks slowly round a large ring this inclination of his body is imperceptible; if he trot there is a visible inclination inwards, and if he gallop he inclines still more, and when urged to full speed he leans very far over on his side, and his feet will be heard to strike against the partition which defines the ring. The explanation of all this is, that the centrifugal force caused by the rapid motion around the ring tends to throw the horse out of, and away from, the circular course, and this he counteracts by leaning inwards.

144 *Why do water-dogs give a semi-rotary movement to their skin to free themselves from water?*

Because in this way a *centrifugal force* is generated, which causes the drops of water adherent to them to fly off.

145 *Why does a person who is about to leap over a ditch or chasm first make a run of a little distance?*

In order that the *impetus he acquires in running* may help him in the jump.

146 *Why is a standing leap always shorter than a running one?*

Because in the running leap, in *addition to the force acquired by the contraction of the muscles*, we have added the *force of the motion* acquired by running.

147 *Why do we kick against the door-post to shake the snow or dust from our shoes?*

The forward motion of the foot is arrested by the impact against the post; but this is not the case with respect to the particles of dust or snow, which are not attached to the foot; but the motion imparted to them equally with the foot is continued, and causes them to fly off.

148 *Why do we beat a coat or carpet to expel the dust?*

The cause which arrests the motion imparted to the coat or carpet by the blow does not arrest the particles of dust, and their motion being continued, they fly off.

149 *Why can birds fly?*

Because they have the largest bones of all animals in proportion to their weight. Air-vessels also enable them to blow out the hollow parts of their bodies, when they wish to make their descent slower, rise more swiftly, or float in the air. The muscles that move the wings of birds downwards, in many instances, are a sixth part of the weight of the whole body; whereas those of a man are not, in proportion, one-hundredth part so large.

It is an erroneous idea, still taught in many educational works, that the bones of birds are hollow and filled with air. This is not the case. Recent investigations have shown that the bones of birds, as a general thing, are not more hollow than those of other animals, and do not contain air.

150 *Why does flying differ from leaping?*

Because flying is the continued suspension and progress of the whole body in the air, by the action of the wings. In leaping, the body is equally suspended in the air; but the suspension is only momentary. In flying, on the contrary, the body remains in the air and acquires a progressive motion by repeated strokes of the wings on the surrounding fluid.

151 *Why do birds stretch out their necks when flying?*

In order that they may act as a wedge, dividing the air and diminishing the resistance.

152 *Why are the strongest feathers of birds in the pinions and tail?*

Because when the wing is expanded, the pinion-feathers may form, as it were, *broad fans*, by which the bird is enabled to raise itself in the air and fly; while its tail-feathers *direct its course.*

153 *Why can a person safely skate with great rapidity over ice which would not support his weight if he moved over it more slowly?*

From the fact that *time is required for producing the fracture of the ice:* as soon as the weight of the skater begins to act on any point, the ice, supported by the water, bends slowly under him; but if the skater's velocity is great, he has passed off from the spot which was loaded before the bending has reached the point which would cause the ice to break.

154 *It sometimes happens when persons are knocked down by carriages that the wheels pass over them with scarcely any injury, though if the weight of the carriage had rested on the body, even for a few seconds, it would have crushed them to death. What explanation can be given of this fact?*

The wheel moves with such rapidity, that *the weight has not time sufficient to exert its full effect.*

155 *When two equal bodies meet, moving with equal velocities in opposite directions, what will be the effect?*

They will both come to rest—for their motion being equal and contrary, will be mutually destroyed.

156 *When two persons strike their heads together, one being in motion and the other at rest, why are both equally hurt?*

Because, when bodies strike each other, *action and reaction are equal;* the head that is at rest returns the blow with equal force to the head that strikes.

157 *When an elastic ball is thrown against the side of a house with a certain force, why does it rebound?*

Because the *side of the house* resists the ball with the *same force*, and the ball, being elastic, *rebounds.*

158 *When the same ball is thrown against a pane of glass with the same force, it goes through, breaking the glass: why does it not rebound as before?*

Because the glass has not sufficient power to resist the full force of the ball: it destroys a part of the force of the ball, but the remainder continuing to act, the ball goes through, shattering the glass.

159 *Why did not the man succeed who undertook to make a fair wind for his pleasure boat, by erecting an immense bellows in the stern, and blowing against the sails?*

Because the action of the stream of wind and the reaction of the sails were exactly equal, and, consequently, the boat remained at rest

160 *If he had blown in a contrary direction from the sails, instead of against them, would the boat have moved?*

It would, with the *same force* that the air issued from the bellows-pipe.

161 *Why cannot a man raise himself over a fence by pulling upon the straps of his boots?*

Because the *action of the force* exerted to raise himself, is *exactly counteracted* by the reaction of the force which tends to keep him down.

162 *Does a man, in rowing, drive the water astern with the same force that he impels the boat forwards?*

He does: *action and reaction being exactly equal.*

163 *Why is it more dangerous to leap from a high window than from a low table?*

Because the *velocity of a falling body*, and, consequently, the force with which it will strike the ground, *increases with the distance* through which it falls.

164 *How far will a body fall, through the influence of gravity, in one second of time?*

Sixteen feet.

165 *How far will it fall in two seconds?*

Four times 16 feet, or 64 feet; in three seconds it will fall 144 feet; in four, 256; in five seconds, 400 feet, and so on.

166 *Will a mass of iron, weighing one hundred pounds, let fall from an elevation, reach the ground any quicker than a mass weighing only one pound, let fall at the same time and from the same place?*

No; the lighter mass will fall with the same velocity, and reach the ground as soon as the larger one.

Before the time of Galileo it was taught and believed, that if two bodies of different weights were let fall from any height at the same moment, the heavier body would reach the ground as much sooner as its weight was greater than the smaller. Galileo, on the contrary, maintained that they would both strike the ground at the same time, and, as his doctrine was generally disbelieved, he challenged his opponents to a practical trial. The experiment was made from the top of the celebrated leaning tower of Pisa, in the presence of a great concourse of people, and resulted in the complete triumph of Galileo.

167 *What is the rule by which the height from which a body falls may be found, the time consumed in falling being known?*

Multiply the square of the number of seconds of time consumed in falling, by the distance which a body will fall in one second.

168 *If a stone is five seconds in falling from the top of a precipice, how high is the precipice?*

The *square* of five seconds is 25; this multiplied by 16, *the number of feet a body will fall in one second*, gives 400, the height of the precipice.

169 *What is a pendulum?*

A *pendulum is a heavy body*, as a piece of metal, *suspended by a wire or cord*, so as to swing backwards and forwards.

170 *When is a pendulum said to vibrate?*

When it swings backwards and forwards; and that part of the circle through which it vibrates, is called its *arc*.

171 *What is a common clock?*

Merely a pendulum, with wheel-work attached to it, to record the number of vibrations, and with a weight or spring, having force sufficient to counteract the retarding effects of friction and the resistance of the air.

172 *How long must a pendulum be to beat seconds?*

About 39 *inches*.

173 *Why does a common clock go faster in winter than in summer?*

Because the pendulum-rod becomes *contracted* by *cold* in winter, and *lengthened* by *heat* in summer.

174. *Why does a change in the length of the pendulum cause a clock to go faster or slower?*

The number of vibrations which a pendulum makes in a given time *depends upon its length*, because a long pendulum does not perform its journey to and from the corresponding points of its arc so soon as a short one.

PART II.

APPLICATION OF THE LAWS AND PROPERTIES OF MATTER TO THE ARTS.

CHAPTER I.

HOW WE APPLY POWER.

175 *What is a machine?*

By a machine we understand a *combination of mechanical powers* adapted to vary the direction, application, and intensity of a moving force, *so as to produce a given result.*

176 *What is the difference between a machine and a tool?*

The difference between *a machine and a tool* is not capable of very precise distinction. A tool is usually *more simple* than a machine: it is generally used *by hand*, while a machine is generally moved by *some other than human power.*

177 *Does a machine ever create power, or increase the quantity of power or force applied to it?*

A machine will enable us to *concentrate or divide* any kind or quantity of force which we may possess, but it no more increases the quantity of force than a mill-pond increases the quantity of water flowing in the stream.

178 *From what sources do we derive advantages by the use of machines and manufactures?*

From the *addition* they make to human *power;* from the *economy* they produce of human *time;* from the *conversion* of substances apparently common and worthless into *valuable products.*

179 *How do machines make additions to human power?*

They enable us to use the powers of *natural agents*, as *wind*, *water*, *steam;* they also enable us to use *animal power* with greater effect, as when we move an object easily with a lever, which we could not with the unaided hand.

180 *How do machines produce economy of human time?*

They accomplish with rapidity what would require the hand unaided much time to perform. A machine turns a gun-stock in a few minutes; to shape it by hand would be the work of hours.

181 *How do machines convert objects apparently worthless into valuable products?*

By their *great power, economy, and rapidity of action*, they make it profitable to use objects for manufacturing purposes which it would be unprofitable or impossible to use if they were to be manufactured by hand. Without machines, iron could not be forged into shafts for gigantic engines; fibres could not be twisted into cables; granite, in large masses, could not be transported from the quarries.

182 *Why are so many attempts continually made to produce mechanical engines which shall generate perpetual motion?*

Because the projectors do not understand the great truth, *that no form or combination of machinery can, under any circumstances, increase the quantity of power applied.*

183 *What is the object of a machine?*

To *receive and distribute motion* derived from an external agent, since no machine is capable of generating motion or moving-power within itself.

184 *What are the principal sources from whence power is obtained?*

Men and *animals*, *water*, *wind*, *steam*, and *gunpowder*. The power of all these may be ultimately resolved into those of muscular energy, gravity, heat, and chemical affinity.

185 *Are there any other sources of power?*

Yes; *magnetism*, *electricity*, *capillary attraction*, etc.;

but none of these are capable of being used practically for the production of motion.

186 *How is muscular energy exerted?*

Through the *contraction of the fibres which constitute animal muscles.* The bones act as levers to facilitate and direct the application of this force, the muscles operating on them through the medium of tendons, or otherwise.

187 *What animals possess the greatest amount of muscular power?*

Beasts of prey. Some very small creatures, however, possess muscular power in proportion to their bulk, incomparably greater than that of the largest and greatest of the brute creation. A *flea*, considered relatively to its size, is far stronger than an *elephant* or a *lion.*

188 *In what method can a man exert the greatest active strength?*

In *pulling upwards from his feet;* because the strong muscles of the back, as well as those of the upper and lower extremities, are then brought advantageously into action. Hence the action of rowing is one of the most advantageous modes of muscular action.

189 *What is the estimate of the uniform strength of an ordinary man for the performance of daily mechanical labor?*

That he can raise *a weight of* 10 *pounds to the height of* 10 *feet once in a second*, and continue to labor for 10 *hours in the day.*

190 *What is a "horse-power?" We say a steam-engine is of a certain horse-power; what is the meaning of the term?*

The *measure of a "horse's power,"* adopted as a standard for estimating the power of steam-engines, is *that he can raise a weight of* 33,000 *pounds to the height of one foot in a minute.*

191 *What is the strength of a horse compared with that of man?*

The force of *one horse* is considered to be equal to that of *five men.*

192 *What do we mean by "water-power?"*

The power obtained by the action of water,—applied generally to the circumference of wheels, which it causes to revolve, either by *its weight*, *by its lateral impulse*, *or by both conjointly.*

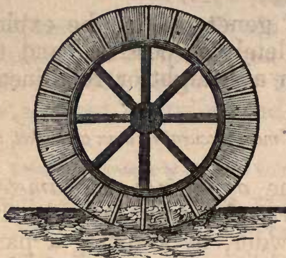


Fig. 8.

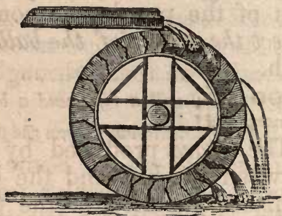


Fig 9.

The most common forms of water-wheels in use are the under-shot and over-shot, or breast-wheels. In the under-shot wheel, *Fig*. 8, a stream of water strikes against the "float-boards" or paddles, placed so as to receive the impulse of the water at right angles to the radii or spokes of the wheel. In over-shot or breast-wheels, *Fig*. 9, the water is received in cells or buckets on the top or side. In this case the wheel revolves through the agency of the weight of the water.

193 *Upon what does the power of steam depend?*

Upon the tendency which *water* possesses *to expand into vapor* when *heated* to a certain temperature.

194 *What is gunpowder?*

A solid explosive substance, composed of *saltpetre* or *nitre*, *sulphur*, and *charcoal*, reduced to powder, and mixed intimately with each other.

195 *Upon what does the power of gunpowder depend?*

When brought in contact with any ignited substance, it explodes with great violence. A vast quantity of *gas, or elastic fluid*, is emitted, the *sudden production* of which, at a *high temperature*, is the cause of the violent effects which this substance produces.

196 *Is the power produced in the explosion of powder ever used for propelling machinery regularly?*

It is not, on account of its *expensiveness* and the *suddenness* and *violence* of its action. It is chiefly applied to the throwing of shot and other projectiles, and the blasting of rocks.

197 *What is the estimated force of gunpowder when exploded?*

At least 14,750 pounds upon every *square inch* of the surface which confines it.

198 *What are the essential properties of a gun?*

To *confine the elastic fluid* generated by the explosion of the powder as completely as possible, and to *direct the course of the ball* in a straight or rectilinear path.

199 *Why will a rifle send a ball more accurately than a musket, or ordinary gun?*

The *space* produced by the *difference of diameter* between the *ball* and the *bore of the gun* greatly diminishes the effect of the powder, by allowing a part of the elastic fluid to escape before the ball, and also permits the ball to deviate from a straight line. The advantage of the rifle-barrel is chiefly derived from the more accurate contact of the ball with the sides of its cavity.

200 *To what distance may a ball be thrown by a twenty-four pounder?*

With a quantity of powder equal to two-thirds the weight of the ball, it may be thrown about four miles.

The effective range of a twenty-four pounder is, however much less than this.

201 *How much further would the same ball go, were the resistance of the air removed?*

About *five times the distance*, or twenty miles.

202 *Why is gunpowder always manufactured in little grains?*

In order to cause it to explode *more quickly*, by facilitating the *passage of the flame* among the particles.

203 *By what terms are cannon of different sizes distinguished?*

By the *weight of the ball* which they are capable of discharging. Thus, we have 68-pounders, 24-pounders, 18-pounders, and the lighter field-pieces, from 4 to 12-pounders.

204 *Are there any more explosive substances than gunpowder?*

Very many; but all of them are too expensive or dangerous for practical use.

205 *By whom was gunpowder supposed to have been discovered?*

It is generally agreed that gunpowder was used by the *Chinese* many centuries before the Christian era. In Europe, its composition and properties were discovered by *Berthold Schwartz*, a Prussian monk, in the twelfth century. It was first used in battle in 1346.

CHAPTER II.

STRENGTH OF MATERIALS.

206 *When materials are employed for mechanical purposes, upon what does their power or strength, apart from the nature of the material, depend for resisting external force?*

Upon the *shape* of the material, *its bearing*, and the *nature of the force* applied to it.

207 *In what position will a bar or beam sustain the greatest application of force?*

When it is strained *in the direction of its length.*

208 *What do we mean by stiffness of a material?*

It is the resistance to the application of force tending to bend it.

209 *How much stiffer is a beam supported at both ends, than one of half the length firmly fixed at only one end?*

Twice as stiff.

210 *In what form can a given quantity of matter be arranged so as to oppose the greatest resistance to a bending force?*

In the form of a *hollow tube or cylinder.*

211 *Why are the bones of man and animals hollow and cylindrical?*

Because in this form they can with the *least weight* of material sustain the greatest force. In man and animals, the hollow part of the bones is filled with an oily substance called marrow.

212 *Why are the quills of birds hollow and empty of marrow?*

In order that they may possess the greatest strength, and by their lightness assist in flying.

213 *Why are the stems of seeds and grain-bearing plants hollow tubes?*

Because this disposition of matter gives to the stalk its greatest strength, enables it to resist the action of the wind, and sustain, without breaking, the ripened ear of grain or seed.

214 *Is a column with ridges projecting from it, stronger than one that is perfectly smooth?*

It is.

215 *Why is a hollow tube of metal stronger than the same quantity of metal as a solid rod?*

Because its substance *standing farther from the centre*, has a greater power of resisting a bending force.

216 *Of two bodies of similar shape, but of different sizes, which is proportionably the weaker?*

The larger. That a large body may have proportionate strength to a smaller, it must have a greater proportionate amount of material; and beyond a certain limit, no proportions whatever will keep it together; but it will fall in pieces by its own weight.

217 *Why cannot trees attain an unlimited height of trunk?*

Because, beyond a certain limit, the *weight of the material* will overcome the *supporting strength* of the material.

218 *Why is it impracticable to build ships beyond a certain size?*

Because the *weight of the timber* and other materials contained in them tends to cause them to fall apart.

In 1825, two vessels, the largest ever constructed, were built in Canada, of 10,000 tons burden. They were found to be weak from their size alone, and were both lost on their first voyage.

CHAPTER III.

APPLICATION OF MATERIALS FOR ARCHITECTURAL OR STRUCTURAL PURPOSES.

219 *What are cements?*

Cements are for the most part soft or semi-fluid substances which have the *property of becoming hard in time*, and *cohering with other bodies to which they have been applied.*

220 *Of what are the ordinary cements which are called mortars composed?*

Of *quicklime*, *sand*, and *water*.

221 *What is quicklime?*

Quicklime is principally *pure lime*, and is obtained from the limestone rock, ordinary marble, or shells which are composed of carbonate of lime, by calcination. The effect of the burning is to drive off the carbonic acid, leaving the lime pure and uncombined.

222 *What is slacked lime?*

If quicklime obtained as above described be *wet with water*, it instantly swells and cracks, becomes exceedingly hot, and at length falls into a white, soft, impalpable powder. This is denominated "*slacked lime.*"

223 *What is ordinary whitewash?*

A mixture of *slacked lime with water*.

224 *Why should slacked lime intended for mortars be excluded from the air, or used soon after it has been prepared?*

Because if exposed to the air it absorbs *carbonic acid*, and becomes converted again into its former condition of *carbonate of lime*.

225 *Why does mortar become hard after a few days?*

A portion of the *water* evaporates, and the lime by a sort of crystallization adheres to the particles of sand

and unites them together. The lime also gradually becomes converted into carbonate of lime.

226 *What sand is most suitable for the formation of mortar?*

That which is wholly *silicious* and is *sharp;* that is, not having its particles rounded by attrition.

227 *What are the proportions of lime and sand in good mortar?*

The proportions are varied in different places: the amount of *sand*, however, always *exceeds* that of the *lime.* The *more sand* that can be incorporated with the lime the better, provided the necessary degree of plasticity is preserved.

228 *What are water, hydraulic, or Roman cements?*

Those which have the property of *hardening under water*, and of consolidating almost immediately on being mixed.

229 *To what cause do the water-cements owe their property of becoming hard under water?*

The cause is not satisfactorily known: all water-cements contain a portion of *burnt clay*, which probably absorbs immediately all superabundant moisture from the lime, and thus expedites its solidification.

This explanation is rendered more probable from the fact, that if the clay is burnt sufficient to *vitrify* it or convert it into *brick*, it ceases to form a water-cement.

230 *What are the constituents of a water-cement?*

Quicklime, *sand* or *silica*, and a proportion of *clay.*

231 *What is stucco?*

Stucco is composed of various ingredients, generally of "*plaster of Paris*," sometimes of white marble pulverized and mixed with plaster and lime.

232 *What is terra-cotta?*

Literally, *baked clay*, a name given to statues, architectural ornaments, vases, figures, etc., modelled of potters'-clay and fine colorless sand, and afterwards exposed to a most intense heat.

233 *Why are bricks when burned usually of a red color?*

Because the *iron* contained in the clay is converted by the heat into the *red oxide of iron*, and acts in this state as red coloring material.

234 *Why are the bricks manufactured at Chicago, and some other parts of the Western country, of a white or yellow color?*

Because the *clay* of which they are formed does not contain *sufficient iron* to color them.

235 *Why did the children of Israel in making bricks desire to mix straw with the clay?*

The bricks of the Egyptians were composed of clay *simply baked in the sun*, and not burnt. By using straw the clay was held together more firmly and the brick rendered stronger.

236 *Why are the Egyptians enabled to dispense with the process of burning the bricks?*

The extreme dryness of the climate in which they were used enable them to dispense with the burning. Bricks from Egypt and Babylon, which have remained exposed to the open air uninjured for two thousand years, rapidly fall to pieces when transported to a moist climate.

237 *Why do we mix hair with mortar?*

In order to render it *more cohesive* and *stronger*.

338 *What are tiles?*

Plates of burnt clay resembling bricks in composition and manufacture, and used for the coverings of roofs or floors.

239 *What is mastich or mastic?*

The name given to those cements which contain animal or vegetable substances in composition. Mastich used for the external decoration of houses often contains oil and a preparation of lead.

240 *What is putty?*

Putty, used by glaziers in setting window-glass and for other purposes, is composed of whiting and linseed-oil, mixed and worked together. Whiting is simply common chalk ground and purified.

CHAPTER IV.

PRINCIPLES OF ARCHITECTURE

241 *What is architecture?*

In its general sense it is the *art of erecting* buildings. In modern use, this name is often restricted to the external *forms* or *styles* of building.

242 *To what cause do the different varieties of architecture owe their origin?*

To the rude structures which the *climate* or *materials* of any country obliged its early inhabitants to adopt for temporary shelter.

These structures with all their prominent features have been afterwards kept up by their refined and opulent posterity. Thus the Egyptian style of architecture had its origin in the *cavern* or *mound;* the Chinese architecture is modelled from the *tent;* the Grecian is modelled from the *wooden cabin;* and the Gothic from the *bower* of trees.

243 *What kind of shape is it most probable that the first human habitations assumed?*

We have every reason to believe that huts of a *conical* form were first constructed.

244 *Why?*

First, on account of their being easily erected, and as easily removed; secondly, because their declivity on all sides would cause the rain to run off; and, thirdly, owing to their breadth at the base and their gradually growing to a point at the top, they were capable of resisting the ordinary force of the wind.

245 *Are conical huts anywhere in use at the present time?*

Yes; we find them still used by the uncultivated inhabitants of the South Sea Islands, by the American Indians, by the Hottentots, the Kamskatschans, and other uncivilized tribes.

246 *What are the three chief properties of a good building?*

Usefulness, strength, and beauty.

247 *How are they to be attained?*

The proper arrangement of the respective parts of the building will insure its usefulness. Its strength will principally depend on the walls being laid on a good and firm foundation, of sufficient thickness at the bottom, and standing perfectly perpendicular. And if all the parts of a building correspond with each other, and are handsome in themselves, then the architect may rely on its beauty.

248 *What are the essential elementary parts of a building?*

Those which contribute to its *support*, *inclosure*, and *covering*.

249 *What is a pile?*

A *cylinder of wood* or metal *pointed at one extremity* and driven forcibly into the earth, to serve as a support or foundation of some structure. It is generally used in marshy or wet places, where a stable foundation could not otherwise be obtained.

250 *Why are long columns supporting great weights made smaller at the top than at the bottom?*

Because the *lower part of the column* must sustain not only the *weight of the superior part*, but also the *weight which presses equally on the whole column.* Therefore the thickness of the column should gradually decrease from bottom to top.

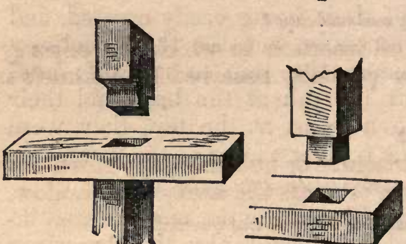


Fig. 10.

251 *In the construction of buildings various terms are employed to designate the method in which the timbers are fitted into each other: what do we mean by mortising?*

Mortising is a *method of insertion* in which the projecting extremity of one timber is received into a perforation in another. (*See fig.* 10.)

252 *Why are steep roofs, or those constructed with considerable inclination, best adapted for houses in cold climates?*

In order that the snow may not be retained upon them, which otherwise would be liable to injure the building by its weight.

253 *What is a mortise?*

The *opening* or *hole* cut in one piece of wood to admit the *projecting extremity* of another piece.

254 *What is a tenon?*

The *end of a piece of timber* which is reduced in dimensions so as to be fitted into a mortise for fastening two timbers together.

255 *What is scarfing and interlocking?*

It is that method of insertion in which the *ends of pieces overlay each other, and are indented together*, so as to resist longitudinal strain by extension, as in tie bearers and the ends of hoops. (*See fig.* 11.)

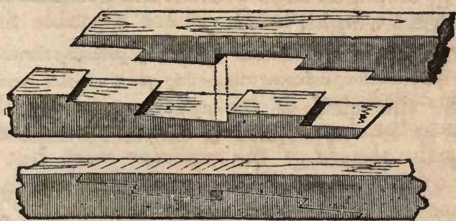


Fig. 11.

256 *What is tongueing and rabbeting?*

It is that method of insertion in which the *edges of boards* are wholly or partially received by *channels* in each other.

257 *What is an arch?*

It is a part of a structure or building suspended over a hollow, and concave towards the area of the hollow.

258 *Is it known at what time the arch was invented?*

It is not; it does not appear to have been known to the ancients.

259 *Why is an arch capable of resisting a greater amount of pressure than a horizontal or rectangular structure constructed of the same materials?*

Because the arrangement of the materials composing the arch is such, that the force which would break a horizontal beam or structure is made to *compress all the particles of the arch alike*, and they are therefore in no danger of being torn or overcome separately.

260 *What is meant by dovetailing?*

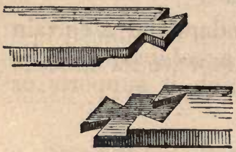


Fig. 12.

It is a method of insertion in which the parts are connected *by wedge-shaped indentations*, which permit them to be separated *only in one direction*. (*See fig.* 12.)

261 *What beautiful application of the arch exists in the human structure?*

In the *skull*, protecting the brain. The materials are here so arranged as to present the greatest strength, with the least weight.

262 *Why is it difficult to break an egg by pressing directly upon its ends?*

Because the *shell of the egg* is constructed on the *principle of the arch*, and is therefore capable of resisting great pressure.

263 *Why is a dished or arched wheel of a carriage much stronger for resisting all kinds of shocks than a flat wheel?*

In an arched or dished wheel, the extremity of a spoke cannot be displaced inwards, or towards the carriage, unless the rim of the wheel be *enlarged*, or all the other spokes yield at the same time; and it cannot be displaced outwards, unless the rim be *diminished*, or the other spokes yield in an opposite direction.

Now the rim, being strongly bound with a tire of iron, cannot suffer either increase or diminution, and the strength of all the spokes is thus conferred by it on each individually. In a *flat* wheel, a given degree of displacement, outwards or inwards, of the extremities of a spoke, would less affect the magnitude of the circumference, and therefore the rim of such a wheel secures it much less firmly.

264 *Why are the fore wheels of carriages smaller than the hind wheels?*

Because they facilitate the turning of the carriage. The advantage of the wheel is proportioned to the magnitude; the smaller wheel having to rise a steeper curve.

265 *What is an abutment?*

The vertical wall which sustains the base, or "spring" of an arch.

266 *What is meant by an order in architecture?*

By an architectural order, we understand a certain mode of *arranging* and *decorating* a *column*, and the adjacent parts of the structure which it supports or adorns.

267 *How many orders are recognised?*

Five:—the *Doric*, *Ionic*, and *Corinthian*, derived from the Greeks; to these the Romans added two others, known as the *Tuscan* and *Composite.*

268 *How do pilasters differ from columns?*

Only in their plan, which is *square*, as that of columns is *round:* pilasters are attached to walls.

269 *What is a portico?*

A portico is a *continued range of columns* covered at the top to shelter from the weather. The portico of the temple at Palmyra was full four thousand feet long.

270 *What are balusters?*

Small columns, or pillars of wood, stone, &c., used in terraces or tops of buildings for ornament; also to support railing. When continued for some distance, they form a balustrade.

271 *Where did the Gothic order of architecture originate?*

Among the *northern nations of Europe.* After the destruction of the Roman empire, it was introduced to the exclusion of the Greek and Roman manner of architecture. It seems particularly adapted to religious edifices.

272 *What are the characteristics of the Gothic architecture?*

Pointed arches, with *greater height than breadth* in the proportions, *with profuse ornament*, chiefly derived from an imitation of the leaves and flowers of plants.

273 *What is said to have been the model of the aisle of a Gothic cathedral?*

A *group of tall trees*, meeting at the top with interwoven branches.

274 *Ought architecture to be considered as a fine or a useful art?*

As a *useful art.*

It is degrading the fine arts to make them entirely subservient to utility. It is out of taste to make a statue of Apollo hold a candle, or a fine painting stand as a fireboard. Our houses are for use, and architecture is therefore one of the useful arts. In building, we should plan the inside first, and then the outside to cover it.

275 *Why is it bad taste to construct a dwelling-house in the form of a Grecian temple?*

Because a Grecian temple was intended for *external worship*, not as a habitation or a place of meeting.

276 *Had the Goths, who plundered Rome, anything to do with the invention of Gothic architecture?*

No; the name was introduced about two hundred years ago as a term of reproach, to stigmatize the edifices of the Middle Ages, which departed from the purity of the antique models.

277 *What is the façade of a building?*

Its front.

278 *What is a pedestal?*

The *lower part* or *base* of the column; a continued base, on which a range of columns is erected, is called a *stylobate.*

279 *What is the base of a column?*

The *lower part*, where it is distinct from the shaft.

280 *What is the shaft?*

The *middle* or longest *part* of the column.

281 *What is the capital?*

The *upper or ornamental part* resting on the shaft. The height of a column is measured in diameters of the column itself, always taken at the base.

282 *What is the plinth?*

This term is applied to the *lower part of the pedestal*, or to any square projecting basis, such as those at the bottom of walls, and under the base of columns. The lower part of the pedestal being called the plinth, the middle part will be termed the *die*, and the upper part the *cornice of the pedestal*. (*See fig.* 13.)

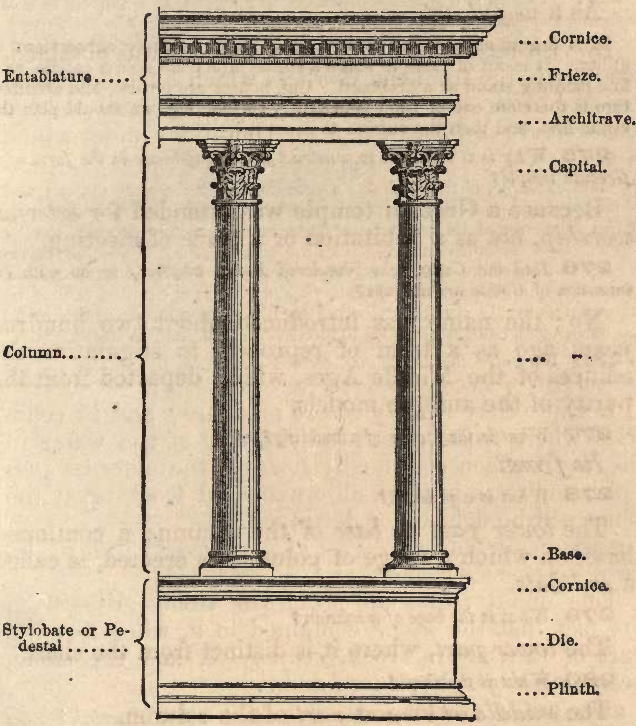


Fig. 13.

283 *What is the entablature?*

The *horizontal continuous portion* which rests upon the top of a row of columns.

284 *What is the architrave?*

The *lower part* of the entablature.

285 *What is the frieze?*

The *middle part* of the entablature.

286 *What is the cornice?*

The *upper or projecting part* of the entablature. (*For illustration of these different terms, see fig.* 13.)

287 *In selecting a stone for architectural purposes, how may we be able to form an opinion respecting its durability and permanence?*

By visiting the locality from whence it was obtained, we may judge from the *surfaces* which have been *long exposed to the weather* if the rock is liable to *yield to atmospheric influences*, and the conditions under which it does so.

"For example, if the rock be a granite, and it be very uneven and rough, it may be inferred that it is not very durable; that the feldspar, which forms one of its component parts, is more readily decomposed by the action of moisture and frost than the quartz, which is another ingredient; and therefore that it is very unsuitable for building purposes. Moreover, if it possesses an iron-brown or rusty appearance, it may be set down as highly perishable, owing to the attraction which this metal has for oxygen, causing the rock to increase in bulk, and so disintegrate."

288 *Why are the sandstones, termed freestones, ill adapted for the external portions of exposed buildings?*

Because they *readily absorb moisture;* and in countries where frosts occur, the *freezing* of the water in the wet surface continually *peels off* the external portions, and thus, in time, all ornamental work upon the stone will be defaced or destroyed.

289 *Why do some species of rock become harder when taken from the quarry and exposed to the atmosphere?*

This quality, in some species of stone, arises from the fact that the *water* contained in it, when forming part of the natural rock, *evaporates*, and the stone, becoming *dryer*, becomes *harder*.

290 *Why do some stones, although hard when first quarried, become friable, and fall to pieces, when exposed to the atmosphere?*

Because they contain *clay* or *alumina* in such a state as to *readily absorb moisture* from the atmosphere; and through the agency of the moisture the particles *lose their cohesion* and fall apart.

PART III.

THE LAWS AND PHENOMENA OF FLUIDS.

291 *Into what two classes may all fluid substances be divided?*

Into liquids, as water, oil, molasses, etc.; and into gases, as common air, carbonic acid gas, oxygen, and others.

292 *What designation do we give to those branches of science, which treat of the laws and phenomena of liquids?*

Hydrostatics, which considers the laws and phenomena of water and other liquids in a state of rest; and hydraulics, which considers the laws and phenomena of liquids in motion.

293 *What designation do we give to that department of science which treats of the laws and phenomena of gases, and other substances resembling air?*

We apply the term Pneumatics to that department of science which explains and illustrates those phenomena which arise from the weight, pressure, or motion of common air and other gaseous bodies.

CHAPTER I.

WATER IN MOTION AND AT REST.

294 *When water or any other fluid is at rest, in what condition is its surface?*

The surface of water at rest is always perfectly level.

295 *Why is the surface of a fluid at rest always level?*

Because the particles are *equally attracted towards the earth by gravity*, and are all equally and perfectly movable among themselves.

296 *How slight a declivity is sufficient to give a running motion to water?*

Three inches to a mile in a smooth, straight channel, gives a velocity of about three miles per hour. The river Ganges, at a distance of 1800 miles from its mouth, is only 800 feet above the level of the sea.

297 *On what principle are we enabled to conduct water under ground through irregular tubes?*

On the principle that water will always *rise to an exact level in different tubes, pipes, or vessels communicating with each other.*

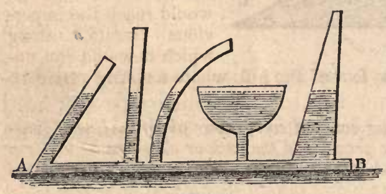


Fig. 14.

If we connect together a series of vessels, no matter how various their shapes and capacities, so that water may rise from the main channel, A B, into them, we shall find upon pouring water into one that it will rise to the same level in all the vessels.

The dependence of all arrangements for conveying water in aqueducts under ground upon the principle, that water in closed tubes or vessels rises to a uniform level, is clearly shown in *Fig.* 15: *a*, *a*, *a*, represents the water-level of a pond or reservoir upon elevated ground. From this pond a line of pipe is laid, passing over a bridge or viaduct at *d*, and

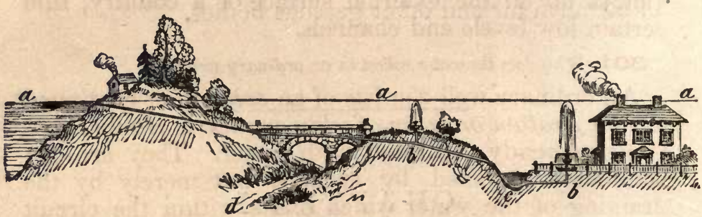


Fig. 15.

under a river at *c*. The fountains, at *b*, *b*, show the stream rising to its level in the pond, *a*, at two points of very different elevation.

298 *In what part of a river does the water flow most rapidly?*

In the *middle of the stream, at the surface.* On the sides and bottom the velocity is diminished by the friction of the water against the banks, bars, etc.

299 *What is the origin of springs?*

The *water* falling upon the earth *sinks downwards* through the sand and porous materials, until an impervious *bed of clay* or rock is reached. Here the *water accumulates*, and finally *bursts out* at some point where the impervious bed or strata comes to the surface in consequence of a valley or excavation.

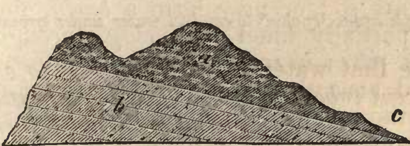


Fig. 16.

Suppose *a* (*Fig.* 16) to be a gravel hill, and *b* a strata of clay or rock, impervious to water. The fluid percolating through the gravel would reach the impervious strata, along which it would run until it found an outlet at *c* at the foot of the hill, where a spring would be formed.

300 *Why does not the water ooze out everywhere along the line of junction of the two formations—the gravel and the rock or clay—so as to form one continuous land soak, instead of a few springs only, and these far distant from one another?*

For *two reasons:* first, on account of *rents and fissures* in the layers of rock, which act as natural drains; secondly, the existence of *inequalities in the surface* of the impermeable stratum, which lead the water, as valleys do on the external surface of a country, into certain low levels and channels.

301 *Why does the water collect in an ordinary well?*

An ordinary well consists of an *excavation* continued until a *stratum or layer of clay or rock is reached* that is permanently saturated with water. They are not commonly supplied by springs, but merely by the draining of the water which exists within the circuit of a few yards into a cavity.

302 *Why do wells and springs fail oftentimes in dry weather?*

Because they are supplied by the *water falling as rain*, which percolates from the surface of the earth.

303 *What is an Artesian well?*

Water is sometimes obtained by *boring into the earth* with a species of auger, until a vein or sheet of water is found, which rises to the surface through the cylindrical excavation. Such excavations are called Artesian wells, because the method was first invented and employed at Artois, in France.

304 *How do you account for the water rising to the surface in Artesian, and sometimes in ordinary wells?*

Strata which are *pervious* frequently alternate with others which are *not* so; or may form a *basin*, the area of which is partially filled with *clay*, through which water cannot pass; in such a case it is obvious that the bed of sand beneath the clay, fed by the rain which descends on the uncovered margin of the basin, must form a reservoir where the water will gradually accumulate beneath the central layer of clay, through which it cannot escape. If the bed of clay be penetrated by natural or artificial means, the water must necessarily rise to the surface, and may even be thrown up in a jet to an altitude which will depend on the level of the fluid in the subterranean reservoir.

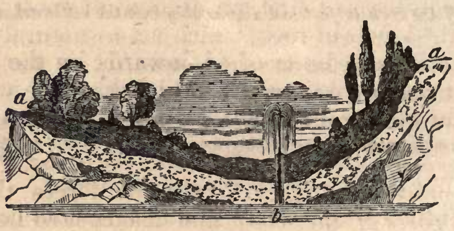


Fig. 17.

Thus, if a sandy stratum, *a a* (*Fig.* 17), acting as a filter, occupies an inclined position between two other strata impervious to water, such as clay, the water being absorbed by the superficial parts of the strata, as at *a a* (which may be of very great extent), will penetrate through its whole depth, and, finding no egress below on account of the basin-like form of the stratum, or from its resting at the lower termination upon a compact rock, will accumulate. The porous strata, therefore, becomes a reservoir to a greater or less extent, and if, by boring through the superincumbent mass, we form an opening into the stratum, as at *b*, the water will rise in it, and flow over in a jet proportional to the height of the water accumulated in the stratum from whence it flows.

305 *What general effect does the cultivation and drainage of a country have upon the springs?*

In a well cultivated and improved country the springs are comparatively few in number and not constant. While the face of a country is rough, the rain-water remains long among its inequalities, slowly sinking into the earth to feed the springs, or slowly running away from bogs and marshes towards the rivers; but in a well drained, country the water runs off quickly, often producing dangerous floods.

306 *How is the pressure of water exerted?*

Equally in all directions.

307 *Does water, contained in a vessel, press with as great force against the sides and top as against the bottom?*

The pressure, in all directions, is the same

308 *What is the result if a corked empty bottle be lowered into the ocean for a considerable depth?*

The cork is generally forced inwards at a given depth, no matter in what direction the mouth of the bottle may happen to point.

309 *If the cork is fastened immovably into the bottle, what will be the effect?*

The bottle will be crushed inwards by the pressure before it reaches a depth of sixty feet.

310 *When a ship founders in shallow water, the wreck, on breaking to pieces, generally comes to the surface and is cast upon the shore; but when a ship sinks in very deep water, it never rises: why is this?*

The *pressure* of very *deep water* forces the water into the *pores of the wood*, and makes it so heavy that no part of the wreck is enabled to rise again.

311 *Can you sink a cork so deep that it will not rise to the surface again?*

At a *great depth* the water forced by *pressure* into the pores of the cork renders it so heavy that it cannot rise.

312 *What is the pressure of water expressed in numbers?*

The pressure of water at any depth, whether on the sides of a vessel or on its bottom, or on any body immersed in it, is nearly one pound on the square inch for every two feet of depth.

313 *What is water?*

Water is a *fluid* composed of *oxygen* and *hydrogen*, in the proportion of eight parts of oxygen to one part of hydrogen.

314 *Why is water fluid?*

Because its *particles* are kept separate by latent heat; when a certain quantity of this latent heat is driven out, *water* becomes solid, and is called ice.

By increasing its *latent heat*, the particles of water are again subdivided into *invisible steam*.

315 *Why is spring water generally called "hard water?"*

Because it is laden with *foreign matters*, and will not readily dissolve substances immersed in it.

316 *What makes spring or well water genearlly hard?*

When it filters through the earth, it becomes impregnated with sulphate of lime, carbonate of lime, carbonic acid, magnesia, and many other impurities, from the *earths and minerals* with which it comes in contact.

317 *What is the cause of mineral springs?*

When water trickles through the ground, it *dissolves* some of the substances with which it comes in contact; if these substances are retained in solution, the water will partake of their mineral character.

318 *When is a mineral water called a chalybeate?*

When it contains *iron*, in some form, dissolved in it.

319 *Mineral springs exist in all parts of our country: what is the nature of the substances contained in them?*

The great majority of them are only *impregnated with iron*, *salt*, or *sulphur*. Some few, however, contain many different substances, as the mineral waters of Saratoga.

320 *Why are springs containing iron in large quantities beneficial to some invalids?*

Because the iron contained in the water acts as a *tonic;* that is, it strengthens and invigorates the system.

321 *What quantity of mineral matter is generally contained in comparatively pure natural waters?*

Any water which contains *less than fifteen grains* of solid mineral matter in a gallon, is considered as *comparatively pure.* Some natural waters are known so pure that they contain only $\frac{1}{20}$th of a grain of mineral matter to the gallon, but such instances are very rare.

Waters obtained from different sources may be classed as regards comparative purity as follows:

Rain water must be considered as the purest natural water, especially that which falls in districts remote from towns or habitations; then comes river water; next, the water of lakes and ponds; next, spring waters; and then the waters of mineral springs. Succeeding these, are the waters of great arms of the ocean into which immense rivers discharge their volumes, as the water of the Black Sea, which is only brackish; then the waters of the ocean itself; then those of the Mediterranean and other inland seas; and last of all, the waters of those lakes which have no outlet, as the Dead Sea, Caspian, Great Salt Lake of Utah, etc. etc.

322 *How much solid matter is ordinarily contained in a gallon of sea water?*

From *twenty-two hundred to twenty-eight hundred grains.*

323 *How much solid matter is contained in a gallon of water from the Dead Sea?*

From *eleven thousand to twenty-one thousand grains,* or nearly one-fourth part of its weight.

324 *Does air exist in all natural waters?*

It *does: fishes* and *other marine animals* are dependent on the air which water contains for their existence.

325 *Would absolutely pure water act as a poison to a fish?*

The fish would *die* of suffocation in such water.

326 *Where is the purest water to be found as a natural product?*

The purest natural water that can be procured is obtained by melting *freshly-fallen snow*, or by receiving rain in clean vessels at a distance from houses.

327 *Why is flowing water not liable to become stagnant?*

Because its *currents carry away* all *contaminating substances* to the sea.

328 *What makes water bubble and sparkle?*

The *air* or *gas* contained in it.

329 *Why does soapy water, especially, bubble?*

Because soap makes water tenacious, and prevents the bubbles from bursting as soon as they are formed.

330 *When soap-bubbles are blown from a pipe, why do they ascend?*

Because they are filled with the warm air of the lungs, which is lighter than cold air.

331 *Why is water fresh from the well or fountain more sparkling and refreshing than the same water after it has been for some time exposed to the air?*

All spring and well waters contain *atmospheric air*, *oxygen*, and *carbonic acid gases*, dissolved in them.

The amount of these substances contained in water, depends upon its temperature, cold water dissolving and retaining a larger quantity than warm or tepid waters. When cold waters from springs or fountains are exposed to the air, they become elevated in temperature, and the gases contained in them escape, rendering the water flat and insipid. The principal agent in imparting a sparkle and freshness to water is atmospheric air, and not carbonic acid, as is often supposed and taught. The quantity of carbonic acid present in ordinary spring waters is generally inconsiderable.

332 *Why is it difficult to wash with hard water?*

Because the water contains *saline matters*, which deprive the water of a part of its solvent power.

333 *Why is it difficult to wash with soap in salt water?*

Because soap is *insoluble in salt water.*

334 *Why does water clean dirty linen?*

Because it dissolves the *stains* as it would dissolve salt.

335 *Why does soap greatly increase the cleansing power of water?*

Because many stains are of a greasy nature; and the alkali of the soap has the power of *uniting with greasy* matters, and rendering them soluble in water.

336 *Why is rain water soft?*

Because it is *not impregnated* with *earths* and *minerals.*

337 *Why is it more easy to wash with soft water than with hard?*

Because soft water *unites freely* with soap and dissolves it; in hard water the soap is either insoluble or becomes decomposed. The solvent power of water increases also with its purity or softness.

338 *When we wash with soap in water what chemical action takes place?*

The soap is resolved into a *fatty substance* and *an alkali;* the alkali dissolves most of the organic substances which constitute the dirt which we wish to remove, and the greasy matter effects by its lubricity an easy washing away of the dissolved matter from other substances.

339 *Why do wood ashes render hard water soft?*

Because they contain a *powerful alkali*—potash, which removes or neutralizes those impurities in the water which rendered it hard and unfit for washing.

340 *Why does sugar or salt give a flavor to water?*

Because the sugar or salt (being separated into *very minute particles*) *floats* about in the water, and mixes with it intimately.

341 *Why does hot water dissolve sugar and salt more readily than cold water?*

Because the heat of the water assists its *solvent action*, and opens for the water a passage through the particles of the substance.

342 *Why is the sea salt?*

The sea has undoubtedly derived all its salt and other soluble mineral substances by *washings from the land.* The streams that have flowed into it for ages have been constantly adding to its quantity, until it has acquired its present condition.

343 *Why is not rain water salt, although most of it is evaporated from the sea?*

Because *salt* will *not evaporate*, and therefore when sea water is turned into vapor, its *salt* is left behind.

344 *Is there more or less of salt in every spring, river, or lake?*

The saline condition of sea water is but an exaggeration of that of all ordinary lakes, rivers, and springs; they all contain *more or less of salt*, but their contents are continually changing and discharging themselves into the sea; therefore the salt does not accumulate.

345 *Is every lake into which rivers flow, and from which there is no outlet except by evaporation, a salt lake?*

It *is;* and it is curious to observe that this condition disappears when an artificial outlet is provided for such waters.

Such lakes are the Dead Sea, the Caspian, the Sea of Aral, and the Great Salt Lake of Utah, the saltness of all of which exceeds that of the ocean.

346 *What good purposes does the presence of so much salt in the ocean subserve?*

It *depresses the freezing point* of the water many degrees, thereby diminishing the dangerous facility with which fields of ice are formed in the polar regions; it also aids in preventing the *corruption of the water* by the accumulation of animal and vegetable remains.

347 *What are the substances extracted from the earth which we find in sea water?*

The most abundant substance is *common salt;* next, certain *combinations of magnesia;* then *salts of lime*, with small proportions of *potash*, *iron*, *iodine*, and *bromine.*

348 *Are these substances found in most springs?*

With the exception of iodine and bromine, they may be found in small quantities in almost *all springs* and rivers.

349 *Are those substances which we call impurities in water of any service to animal or vegetable systems?*

They give to water its *freshness* and *sparkling properties;* pure distilled water is very disagreeable to drink; these substances are also generally beneficial to the systems of plants and animals, and are absorbed by them with the water.

350 *Does water form part of the composition of most bodies?*

It enters directly into the composition of nearly *all crystallizable bodies* and most *organic compounds.*

351 *If the waters of the ocean were not agitated by winds, currents, and tides, what would be the effect?*

The water would become *stagnant.*

352 *Will water contaminated with animal and vegetable matter under some circumstances purify itself?*

Water contaminated with animal and vegetable matter, if kept for some time, undergoes a *spontaneous purification*, losing its offensive odor and color, and depositing more or less sediment. Water, for the supply of ships, is well known to undergo this process of purification by fermentation; and the larger the quantity of destructible matter suspended in it, the more complete and rapid is its purification.

353 *What is a tide?*

A tide is a *wave of the whole ocean*, which is elevated to a certain height, and then sinks, after the manner of a common wave.

354 *What is the cause of tides?*

The *attraction of the sun and moon* upon the waters of the ocean. The moon being nearest to the earth, her attraction is six times greater than that of the sun. This attraction of the moon raises the waters of the ocean as they come under her influence by the motion of the earth on its axis.

355 *How many tides are there in a day?*

Two in every lunar day—a period of 24 hours 49 minutes.

356 *What tides are the highest?*

The *spring tides.*

357 *Why are they higher than at other periods?*

Because the *sun and moon* are then in such a position that they exert their influence *together*. For every five feet of height in tide produced by the moon, the influence of the sun adds one foot.

358 *What are neap tides?*

Low tides.

359 *Why are neap tides lower than other tides?*

Because then the sun and moon have such positions that their attractive influence is *opposed to each other;*

and for every six feet of the moon's tide, the opposite attraction of the sun takes away one foot.

360 *How fast does the tide wave move?*

The rate of movement of the tide wave depends upon the nature and depth of the sea bottom. With a depth of one fathom, its rate is *eight miles per hour;* and with one hundred fathoms, *eighty miles per hour.*

361 *Does the height of the same tide vary in different places?*

The height of the tide in different places depends much on the *configuration of the land;* the same tide may rise in one place three inches, and in another place thirty feet.

362 *At what period during the day is it high water?*

When the moon *passes the meridian*—that is, when it is nearly vertical over the place—the sea is elevated to the greatest extent, and it is said to be high water.

363 *When is it low water?*

When the moon is upon the *horizon*, or about six hours after high tide. As the moon passes the meridian below the horizon, another elevation occurs, so that we have the ebb and flow of the tide twice every day.

364 *How much later does the tidal ebb and flow occur each day?*

The time becomes later every day by about *fifty and a half minutes*, which is the excess of a lunar day above a solar one: 28½ minutes of the former being equal to 27½ minutes of the latter.

365 *What is the cause of ordinary sea waves?*

The *wind*, pressing unequally on the surface of the sea, depresses one part more than another; every depression causes a corresponding elevation, and these undulations are called *waves.*

It must be remembered that waves have no other than a *vertical motion, i.e.* up and down. Any substance, as a buoy, floating on a wave, is merely elevated and depressed alternately; it does not otherwise change its place.

366 *If waves are stationary, and only move up and down, why do they seem to advance towards the shore?*

This is an *ocular deception.* When a *corkscrew* is turned round, the thread appears to move forward; and the apparent *onward* motion of the waves of the sea is a similar delusion.

367 *What is the cause of breakers?*

The interference of *rocks* or *rising banks* in the sea with the regular form of the wave, by which the outline or curve of the wave is broken.

368 *What causes the spray of waves?*

The *wind* driving the *surface* of the *water* from the top of the wave, and scattering the small particles in all directions.

369 *What is the surf?*

When the shore runs out very shallow for a great extent, the *breakers* are distinguished by the name of *surf*.

370 *What do we know concerning the magnitude and velocity of ocean waves?*

On the Atlantic, during a storm, the waves rise to a height of about *forty-three feet* above the hollow occupied by the ship; the total distance between the crests of two large waves being 559 feet, which distance is passed by the wave in about seventeen seconds of time.

371 *With what velocity is it estimated that such storm waves as the above described travel?*

At the rate of about *thirty-two miles per hour.*

A wave is a *form*, and not a thing; the *form* advances, but not the *substance* of the waves.

372 *If a cock at the extremity of a pipe be suddenly closed while water is running through, why is a noise and shock produced?*

Because the *forward motion* of the whole body of the water contained in the pipe being *instantly arrested*, and the momentum of a liquid being as great as that of a solid, the water strikes the cock with as much force as if it were a long bar of metal, or a rod of wood having the *same weight and velocity* as the water. Then, as a fluid presses equally in all directions, a leaden pipe of great length may be widened, or even burst in the experiment.

CHAPTER II.

SPECIFIC GRAVITY.

373 *Why does ice float upon water?*

Because it is *lighter* than water.

374 *Why does iron sink in water?*

Because it is *heavier* than water.

375 *If we put a piece of ice in alcohol, it sinks; if we put a piece of iron upon quicksilver, it floats: why is this?*

Because the *ice is heavier* than the alcohol, and the *iron is lighter* than the quicksilver.

376 *What do we mean, when we say that ice is lighter than iron?*

We mean that, taking *equal bulks* of each, the former weighs less than the latter; and when we say that quicksilver is heavier than water, we mean that, in *equal volumes*, as a pint, for instance, the quicksilver has a greater weight than the water.

377 *What, then, is specific gravity?*

It is the *weight* of a body compared with the weight of an *equal bulk* of water.

378 *How does it differ from ordinary or absolute weight?*

In *absolute weight* no regard is paid to the *volume* or *bulk* of substances. In specific weight, a given bulk or volume is compared with an equal volume or bulk of water.

379 *What body has the greatest specific weight?*

Purified platina, which is 22 times heavier than an equal bulk of water.

380 *What substance has the smallest specific weight?*

Hydrogen gas, which is 12,000 times lighter than an equal bulk of water.

381 *Why will an egg float in strong brine, and not in fresh water?*

Because the solution of a solid in any liquid increases its *density*, or its *specific gravity:* the addition of salt to the water, renders the specific gravity of the brine greater than that of fresh water, or of the egg.

382 *How do cooks sometimes ascertain if their brine be salt enough for pickling?*

They put an *egg into their brine.* If the egg *sinks,* the brine is *not strong enough;* if the egg *floats,* it *is.*

383 *Why will an egg sink, if the brine be not strong enough for pickling?*

Because an egg will be the *heavier;* but if as much *salt* be added as the water can dissolve, an egg will be lighter than the strong brine, and consequently float on the surface.

384 *Why is it more easy to swim in the sea than in a river?*

Because the *specific gravity* of salt water is *greater* than that of fresh; and, therefore, it *buoys* up the swimmer better.

385 *Why do persons sink in water when they are unskilful swimmers?*

Because they struggle to keep their *head out of water.*

386 *Explain how this is?*

When our head is thrown back boldly into the water, our mouth is kept *above the surface*, and we are able to breathe; but when the head is kept *above the surface* of the water, the chin and mouth sink *beneath* it, and the swimmer is suffocated.

This may be illustrated thus:—If a piece of wood be of such specific gravity that only *two square inches* can float out of water, it is manifest, that if two *other* inches are raised out, the two *former* inches must be plunged *in.* The body (in floating) resembles this piece of wood. If two square inches of our *face* float out of the water, we can breathe; but if part of the *back* and *crown* of the head are raised above the water, the lower part of the face will be depressed beneath it.

387 *Why can quadrupeds swim more easily than man?*

1. Because the *trunk* of quadrupeds is *lighter* than water, and this is the greater part of them; and

2. The *position* of a beast (when swimming) is a *natural* one.

388 *Why is it more difficult for a man to swim than for a beast?*

1. Because his body is more heavy in proportion than that of a beast; and

2. The position and muscular action of a *man* (when swimming) differ greatly from his ordinary habits; but beasts swim in their ordinary position.

389 *Why can fat men swim more easily than spare men?*

Because *fat is lighter than water;* and the *fatter* a man is, the more *buoyant* will he be.

390 *How are fishes able to ascend to the surface of water?*

Fishes have an *air-bladder* near the abdomen; when this air-vessel is distended, the fish increases in size and (being lighter) ascends through the water to its surface.

391 *How are fishes able to dive in a minute to the bottom of a stream?*

They *compress the air* in their air-bladder; in consequence of which their *size is diminished*, and they sink instantly.

392 *Why does the body of a drowned person rise and float upon the surface several days after death?*

Because, from the *accumulation of gas* within the body (caused by incipient putrefaction), the body becomes specifically lighter than water, and rises and floats upon the surface.

393 *How are life-boats prevented from sinking?*

They contain in their sides *air-tight cells*, or *boxes* filled with air, which by their buoyancy prevent the boat from sinking even when it is filled with water.

394 *The slaves of the West Indies have a plan of stealing rum from a cask, by inserting the long neck of a bottle, full of water, through the bung. How are they enabled in this manner to obtain the rum?*

The *rum* is very much *lighter* than the *water;* and as the *heavy water* falls out of the bottle into the cask, the *lighter rum* rises to take its place.

395 *Why does cream rise upon milk?*

Because it is composed of particles of *oily* or *fatty* matter, which are lighter than the *watery* particles of the milk.

396 *Why do stale eggs float upon water?*

Because, by keeping, *air* is substituted for a portion of the *water* of the egg, which escapes.

397 *Why does not a vessel constructed of iron sink, as the iron is much heavier than the water?*

Because the vessel is constructed in a *concave* form, and is thus rendered buoyant. Every substance becomes lighter in water, *in proportion to the amount of water displaced.* This is a law of nature: if it displaces less water than its weight in air, it sinks; if more, it floats. The ship, being concave, displaces a greater weight of water than the weight of the iron of which it is composed in the air.

A thick piece of iron, weighing half an ounce, loses in water nearly one-eighth of its weight; but if it is hammered out into a plate or vessel, of such a size that it occupies eight times as much space as before, it then loses its whole weight in water, and will float, sinking just to the brim. If made twice as large, it will displace one ounce of water, consequently, twice its own weight; it will then sink to the middle, and can be loaded with half an ounce weight before sinking entirely.

398 *Why are stones, gravel, and sand so easily moved by waves and currents?*

Because the moving water has only to overcome about *half the weight* of the stone.

399 *Why can a stone which, on land, requires the strength of two men to lift it, be lifted and carried in water by one man?*

Because the *water holds up the stone* with a force equal to the weight of the volume of water it displaces.

CHAPTER III.

CAPILLARY ATTRACTION.

400 *Why does water melt salt?*

Because very minute particles of water insinuate themselves into the *pores* of the salt by *capillary attraction*, and force the crystals apart from each other.

401 *Why does water melt sugar?*

Because very minute particles of water insinuate themselves into the *pores* of the sugar by *capillary attraction*, and force the crystals apart from each other.

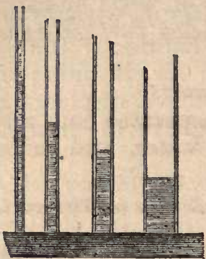


Fig. 18.

402 *What is capillary attraction?*

The power which very minute tubes possess of causing liquid to *rise in them above its level.*

"*Capillary*," from the Latin word, "capillaris" (*like a hair*); the tubes referred to are almost as fine and delicate as a hair. Water ascends through a lump of sugar or piece of sponge, by capillary attraction.

N. B. The smaller the tube, the higher will the liquid be attracted by it. *Fig.* 18 illustrates the manner in which water will rise in tubes of different diameters.

403 *Why is vegetation on the margin of a river more luxuriant than in an open field?*

Because the porous earth on the bank *draws up water* to the roots of the plants by *capillary attraction.*

404 *Why do persons who water plants very often pour the water into the saucer, and not over the plants?*

Because the water in the saucer is *drawn up* by the mould (through the hole at the bottom of the flower-pot), and is transferred to the stem and leaves of the plant by *capillary attraction.*

405 *Why is cotton best adapted for lamp-wicks?*

Because the arrangement of the fibres of the cotton-wick is such, that the whole forms a *bundle of minute tubes*, in which the oil ascends and supplies the flame by *capillary attraction.*

406 *Why does blotting-paper absorb ink?*

The *ink* is drawn up between the *minute fibres* of the paper by *capillary attraction.*

407 *Why will not writing or sized paper absorb ink?*

Because the *sizing*, being a species of glue into which writing papers are dipped, *fills up the little interstices or spaces between the fibres*, and in this way prevents all capillary attraction.

408 *How does a sponge absorb water?*

The *pores* of the sponge constitute *minute tubes* in which the water rises by capillary attraction.

409 *Why does dry wood, immersed in water, swell?*

Because the *water enters the pores* of wood by capillary attraction, and *forces* the particles *further apart* from each other.

410 *Why does sugar or salt give a flavor to water?*

Because the sugar or salt (being separated into *very minute particles*) *floats* about the water, and mixes with it intimately.

411 *Why does hot water dissolve sugar and salt more readily than cold water?*

Because the heat of the water assists its *solvent action*, and opens for the water a passage through the particles of the substance.

CHAPTER IV.

THE GENERAL PROPERTIES OF AERIFORM OR GASEOUS BODIES.

412 *What is the difference between a liquid and a gas?*

The distinction between liquids and those more elastic fluids which we term air, gas, vapor, steam, etc., depends principally *on heat and pressure.* Thus, water, according to the addition or subtraction of heat, may exist as a solid, ice; as a liquid, water; or as a vapor, steam.

413 *Under what pressure of the atmosphere is water converted into steam?*

Under the ordinary pressure of the atmosphere, water is converted into steam at 212 degrees, Fahrenheit's thermometer; if this pressure is increased, it requires a proportionably higher temperature; if this pressure is diminished, the amount of heat required is proportionably less.

414 *How many kinds of aeriform or gaseous bodies exist in nature?*

Those which, under *common circumstances of temperature and pressure*, are always in a gaseous state, as common air; and those which become gases *chiefly at high temperature*, as steam, or vapor of water.

415 *Are all gases invisible or colorless like atmospheric air?*

Some gases possess color, but the greater number are colorless and invisible.

416 *Of what is atmospheric air composed?*

Principally of two gases, *oxygen* and *nitrogen*, mixed together in the following proportion: viz. one volume of oxygen to four of nitrogen.

It must not be forgotten that the air contains small quantities of other gaseous substances also, as *vapor of water*, *carbonic acid*, and *ammonia*.

417 *Do the particles of which atmospheric air and other gaseous bodies are composed, appear to have any cohesion between themselves?*

The ultimate particles of which air and other gases are composed appear to be destitute of cohesion; hence air has a disposition not only to sink down and spread out laterally, like liquids when unconfined, but also to expand and rise upwards.

418 *Is the air porous?*

Yes; in a *very high degree.*

419 *How do we know this fact?*

Because air readily yields to pressure, and a great bulk of it may be forced to occupy a very small space.

420 *Is air also impenetrable?*

Yes; *beyond a certain limit* it cannot be compressed.

421 *How much lighter is steam than ordinary air?*

Steam has but little more than *half the weight of atmospheric air;* and hence it rises and floats in the air as a cork rises and floats in water.

CHAPTER V.

THE ATMOSPHERE.

422 *What do we understand by the atmosphere?*

The thin transparent fluid which surrounds the earth to a considerable height above its surface, and which, by its peculiar constitution, supports animal life by respiration, and is also necessary for the due exercise of the vegetable functions.

423 *Is the atmosphere invisible?*

It is generally, but erroneously, so regarded. *The atmosphere is not invisible.*

424 *How can you prove that the atmosphere is not invisible?*

Because when we look upwards into the firmament on a clear day, the space appears of *an azure or clear color.* This color belongs not to anything which occupies the space in which the stars or other celestial objects are placed, but to the mass of air through which the bodies are seen.

425 *Why do distant mountains appear blue?*

Not because it is their color, but because it is *the color of the air through which they are seen.*

426 *Has air weight?*

It has; as well as lead, stone, or any other material substance.

427 *How can this be readily proved?*

By weighing a vessel filled with air, and the same vessel after the air has been exhausted from it.

428 *Can the existence of air be known by the sense of touch or feeling?*

It can; since *it opposes resistance when acted upon*, and strikes with a force proportionate to the speed of its motion.

429 *Why do we always feel a breeze on the deck of a steamboat in motion, even upon the calmest day?*

Because our bodies *forcibly displace the air as we are carried through it.*

430 *How are waves of the ocean produced?*

By the *force of the air in motion*, or wind striking upon the surface of the water.

431 *Could a bird fly in a space devoid of air, even if it could exist without respiration?*

It could *not;* as the bird rises simply by the *resistance* of the particles of air to the beating of its wings.

432 *How do we know that air is elastic?*

Because a volume of compressed air, the pressure being removed, immediately restores itself to its original bulk.

433 *When is air said to be rarefied?*

When a given quantity of air is caused to expand and occupy a greater space, it is said to be *rarefied.*

When a part of the air inclosed in any vessel is withdrawn, that which remains, expanding by its elastic property, always fills the dimensions of the vessel as completely as before. If nine-tenths were withdrawn, the remaining one-tenth would occupy the same space that the whole did formerly.

434 *What is the height of the atmosphere above the surface of the earth?*

It is supposed to be about 45 *miles;* the zone or shell of air which surrounds the earth to the height of nearly 2¾ miles from its surface, contains one-half of the atmosphere; and the remaining half being relieved of this superincumbent pressure, expands into another zone or belt of the thickness of 41 or 42 miles.

Some authorities suppose this last zone to have a much greater area.

435 *What is the weight of air compared with that of water?*

Water is about 840 *times* the weight of air, taken *bulk for bulk.*

436 *What is the estimated weight of the whole atmosphere enveloping the globe?*

To the weight of a *globe of lead sixty miles in diameter.*

437 *As air has weight, and as the mass of it extends at least* 45 *miles above the earth's surface, what amount of pressure does it exert?*

At the *level of the ocean* the atmosphere exerts a pressure of about 15 *pounds for every square inch of surface.*

438 *If the air were condensed, so as to occupy no more space than the same weight of water, to how great an elevation above the earth would it extend?*

To an elevation of *thirty-four feet.*

439 *In what direction is the pressure of the atmosphere exerted?*

It is the nature of a fluid to transmit pressure in *every direction equally;* therefore the air presses *upwards*, *downwards*, *laterally*, and *obliquely*, with the same force.

440 *How great a pressure is exerted by the air upon the body of a man or animal having a surface of* 2000 *square inches?*

Not less than 30,000 *pounds*, or *about* 15 *tons.*

441 *Why is not the individual crushed beneath so enormous a load?*

Because the atmosphere *presses equally in all directions*, and *our bodies are filled with liquids* capable of sustaining pressure, or with *air of the same density* as the external air; so that the *external pressure* is met and counteracted by the *internal resistance.*

442 *What would be the effect upon a man or animal if at once relieved of all atmospheric pressure?*

All the *blood* and *fluids* of the body would be *forced by expansion to the surface*, and the animal would burst.

443 *What do we mean by a vacuum?*

A space devoid of all matter; in general, we mean by a vacuum, a space devoid of air.

444 *Can a perfect vacuum be produced artificially?*

No; but confined spaces may be deprived of air sufficiently for all experimental or practical purposes.

445 *Are there any instances of a vacuum in nature?*

There is no positive certainty that the spaces which exist between the various planets and other heavenly bodies, are occupied with any material substance.

446 *Is the existence of air necessary to the production of sound?*

It is; in a *vacuum* there can be *no sound;* and on the top of high mountains, where the air is greatly rarefied, as on Mont Blanc, the report of a pistol can hardly be heard.

447 *Why is it often painful and difficult to breathe on a mountain-top?*

Because, owing to the *extreme rarity* of the air on the top of the mountain, a person, although expanding his chest as much as usual, really takes in only half as much air as he does when at the foot of the mountain.

448 *If the lips be applied to the back of the hand, and the breath drawn in so as to produce a partial vacuum in the mouth, why will the skin be drawn or sucked in?*

Not from any force resident in the lips or the mouth drawing the skin in, but from the fact that the usual external pressure of air is removed, and that the *pressure from within the skin* is suffered to prevail.

449 *How is a boy enabled to lift a stone by means of the common sucker?*

The sucker consists of a *disk of moistened leather*, with a string by which it may be suspended with any weight attached to it. If its smooth moist surface be pressed so closely against the flat side of a stone or other body that the air cannot enter between them, the weight of the atmosphere pressing upon the upper surface of the leather makes it adhere so strongly, that a stone of weight proportioned to the extent of the disk of leather may be raised by lifting the string.

450 *How are flies and other small insects enabled to walk on ceilings and surfaces presented downwards, or upon smooth panes of glass in an upright position?*

Their feet are formed in such a manner that they *act as small air-pumps or suckers*, excluding the air between them and the surface with which they are in contact; and the atmospheric pressure keeps the animal in position.

451 *Why in breathing do we first draw in the breath, as it is termed?*

Because by so doing we make *an enlarged space in the chest*, and the *pressure of the external atmosphere* forces the air in to fill it.

The air enters the lungs, not because they draw it in, but by the weight of the atmosphere forcing it into an empty space.

452 *How is the air caused to escape from the lungs?*

Simply by means of its *elasticity;* the lungs by muscular action compress the air contained in them, and give to it by compression a greater elasticity than the air without. By the excess of the elasticity it is propelled, and escapes by the mouth and nose.

453 *Why does a bottle or jug gurgle when liquid is freely poured from it?*

On account of the *pressure of the atmosphere forcing air* into the interior of the bottle. In the first instance, the neck of the bottle is filled with liquid, so as to stop the admission of air. When a part has flowed out, and an empty space is formed within the bottle, the atmospheric pressure forces in a bubble of air through the liquid in the neck, which, by rushing suddenly into the interior of the bottle, produces the sound.

454 *How long will a bottle continue to gurgle?*

So long as the neck continues to be choked with liquid. But as the contents of the bottle are discharged, the liquid, in flowing out, only partially fills the neck; and, while a stream passes out through the lower half of the neck, a stream of air passes in through the upper part. The flow being now continued and uninterrupted, no sound takes place.

455 *Does air exist in water?*

Water, and most liquids exposed to the air, *absorb a greater or less quantity*, which is maintained in them by the pressure of the atmosphere acting on the surface.

456 *Why is boiled water flat and insipid?*

Because the *agency of the heat expels the air* which the water previously contained.

457 *Could fishes and other marine animals live in water deprived of air?*

They could not, as they breathe the air contained in the water.

458 *Why do ale, porter, and cider froth, and champagne sparkle, when uncorked and poured into an open vessel?*

When these liquors are bottled, the *air* confined under the cork *is condensed*, and exerts upon the surface a *pressure greater* than that of the atmosphere.

This has the effect of holding, in combination with the liquor, air or gas which, under the atmospheric pressure only, would escape. If any air or gas rise from the liquor after being bottled, it causes a still greater condensation, and an increased pressure above its surface. When the cork is drawn from a bottle containing liquor of this kind, the air fixed in the liquid, being released from the pressure of the air which was condensed under the cork, instantly makes its escape, and, rising in bubbles, produces effervescence and froth.

459 *Why do bottles containing ale, cider, porter, &c., frequently burst?*

It is the nature of these liquids to produce *gas or air* in considerable quantities, *the elastic force of which* sometimes becomes greater than the cohesive strength of the particles of matter composing the bottle, which then necessarily gives way, or bursts.

460 *Why does one kind of liquor froth, and another kind only sparkle?*

Those liquors only which are *viscid*, *glutinous*, *or thick*, *froth*, because they retain the little bubbles of air as they rise; while a thin liquor, like champagne, suffers the bubbles to escape readily.

CHAPTER VI.

ATMOSPHERICAL PHENOMENA.

461 *What designation do we give to that department of science which treats of the various phenomena of the atmosphere?*

Meteorology.

462 *How is the air heated?*

In two ways; either by the rays of the sun passing through it, or by the heat communicated to it by the earth.

463 *In what manner is the air heated by the earth?*

The *sun* heats the *earth*, and the *earth* heats the *air resting upon it;* the air thus heated *rises*, and is succeeded by *other air*, which is heated in a similar way, till the whole volume is *warmed.*

464 *How is the air made cold?*

2 The air resting on the earth is made *cold* by *contact;* this cold air makes the *air above it cold;* and cold currents (or winds) cause the whole to mix together, until all becomes of one temperatnre.

465 *What effect is produced upon air by cold?*

3 It is *condensed* or compacted into a smaller compass; in consequence of which *it becomes heavier*, and descends towards the ground.

466 *Prove that the air is condensed by cold.*

4 Lay a bladder half full of air before a fire, till it has become *inflated;* if it be now removed *from* the fire, the bladder will *collapse* again, because the air condenses into its former bulk.

5 467 *What effects has heat upon air?*

Heat *rarefies* or makes it lighter; that is, a quantity of air heated will occupy more space than the same quantity which has been cooled.

468 *What is wind?*

Wind is *air put in motion.*

7 469 *What occasions those movements of the air which we call wind?*

The principal cause is the *variation of temperature* produced by the alternation of day and night and the succession of the seasons.

470 *How can winds originate through variations of temperature?*

When through the agency of the sun a particular portion of the earth's surface is heated to a greater degree than the remainder, the air resting upon it becomes *rarefied* and *ascends*, while a current of cold air rushes in to supply the vacancy. Two currents, the one of warm air flowing out, and the other of cold air flowing in, are thus continually produced; and to these movements of the atmosphere we apply the designation of *wind*.

471 *Does the wind always blow?*

Yes; there is always *some motion* in the air; but the *violence* of the motion is perpetually varying.

472 *Does the rotation of the earth upon its axis affect the motion of the air?*

Yes, in *two ways:* 1. As the earth moves round its axis, the thin movable air is left somewhat *behind*, and therefore seems (to a stationary object) to be blowing in the *opposite* direction to the earth's motion; and

2. As the earth revolves, *different portions* of its surface are continually passing under the *vertical rays of the sun.*

473 *When are the rays of the sun called vertical rays?*

When the sun is in a *direct line* above any place, his rays are said to be "vertical" to that place.

474 *When the sun is vertical, or nearly over head at any place, what time of day is it at that place?*

Noon.

475 *How does a change in the heat of air produce wind?*

The air always seeks to *preserve an equilibrium;* so *cold air* rushes into the *void* made by the *upward current of warm air.*

476 *Why does not the wind always blow one way, following the direction of the sun?*

Because the direction of the wind is subject to perpetual interruption from *hills* and *valleys*, *deserts*, *seas*, &c.

477 *How can hills or mountains affect or change the direction and course of the wind?*

If a current of air, blowing from a particular direction, strike against the side of a mountain, it will necessarily be *deflected from a straight line*, and must either *ascend* the mountain, *turn back*, or assume a *lateral direction.*

478 *Why are those winds which blow over large continents or tracts of land generally dry?*

Because in their passage they *absorb* very *little water*, as they do not blow over large oceans.

7 **479** *Why do our hands and lips chap in frosty and windy weather?*

Because a cold, dry wind absorbs moisture from the surface of the skin ; and this action, in turn, causes the skin to crack and inflame.

8 **480** *Would the wind blow regularly from east to west if all obstructions were removed?*

Without doubt. If the whole earth were covered with *water*, the winds would always *follow the sun*, and blow uniformly in *one direction.*

9 **481** *Do winds ever blow regularly?*

Yes, in those parts of the world which present a *large surface of water*, as in the Atlantic and Pacific Oceans.

10 **482** *With what velocity do winds move?*

Every graduation exists in the speed of winds, from the mildest zephyr to the most violent hurricane.

483 *With what velocity does a wind which is hardly perceptible move?*

With a velocity of about *one mile per hour*, and with a perpendicular force on one square foot of ·005 lbs. avoirdupois.

484 *In a gentle wind, what is the velocity and estimated pressure?*

From *four to five miles per hour*, and a force of ·079 to 123 lbs.*

485 *In a very brisk wind, what is the velocity and pressure?*

From *twenty to twenty-five miles per hour ;* force 1·9 to 3·07 lbs.

486 *What is the velocity and pressure of the wind in a storm?*

From *fifty to sixty miles per hour*, with a pressure of 7 to 12 lbs.

487 *In a hurricane, what is the estimated velocity and pressure?*

From *eighty to one hundred miles per hour*, with a varying force of 31 to 50 lbs.

* In these estimates the pressure is computed per square foot in pounds avoirdupois.

488 *Why do we sometimes see clouds at one elevation moving in one direction, and at another elevation, at the same time, others moving in a contrary direction?*

Because *different currents of air* exist at *different elevations*, moving in different directions, with different velocities.

In 1839, an English aeronaut, at the height of 14,000 feet, encountered a current that bore him along at the rate of five miles per hour; but, upon descending to the altitude of 12,000 feet, he met with a contrary wind, blowing with a velocity of eighty miles per hour.

489 *How is the force of the wind ascertained?*

By observing the *amount of pressure* that it exerts upon a given plane surface *perpendicular to its own direction.*

If the pressure plate acts freely upon spiral springs, the power of the wind is denoted by the extent of their compression, and that weight will be a measure of their force, the same as in weighing by the ordinary spring-balance.

490 *What is an instrument for measuring the force of the wind called?*

An *Anemometer.*

491 *What are the constant winds which blow over the Atlantic and Pacific Oceans called?*

They are called "*trade-winds.*"

492 *Why are they called trade-winds?*

Because they are very convenient to *navigators* who have to cross the ocean, inasmuch as they always blow in *one direction.*

493 *In what direction do the trade-winds blow?*

That in the northern hemisphere blows from the north-east; that in the southern hemisphere from the south-east.

494 *Do trade-winds blow from the north-east and south-east all the year round?*

Yes, *in the open sea;* that is in the Atlantic and Pacific oceans, for about 25° each side of the equator.

495 *Where do the trade-winds blow with uniform force and constancy?*

In many parts of the Pacific embraced within the region of the trade-winds, a vessel may *sail for a week* without *altering the position of a sail* or rope.

496 *Why does a sea breeze feel cool?*

Because the sun cannot make the surface of the *sea* so hot as the *land;* therefore the air which blows from the sea is *cooler than the air of the land.*

497 *Why is there generally a fresh breeze from the sea during the summer and autumn mornings?*

Because *land* is *more heated by the sun* than the *sea* is; and the *land* air becomes hotter than that over the *sea;* in consequence of which the cooler sea air glides *inland* to restore the equilibrium.

498 *Why are the west winds in the Atlantic States generally dry?*

Because they come over *large tracts of land*, and therefore absorb *very little water;* and being thirsty, they readily imbibe moisture from the air and clouds, and therefore *bring dry weather.*

499 *Why is the north wind generally cold?*

Because it comes from the *polar regions*, over mountains of snow and seas of ice.

500 *Why are north winds generally dry?*

Because they come from *colder* regions, and being *warmed* by the heat of our climate, *absorb moisture* from everything they touch; in consequence of which they are generally dry.

501 *Why are south winds generally warm?*

Because they come over countries warmer than our own, where they are much heated.

502 *Why are winds which blow over a vast body of water generally rainy?*

Because they come laden with *vapor;* if, therefore, they meet with the least *chill*, some of the vapor is deposited as rain.

503 *Why is there often an evening breeze during the summer months?*

Because the earth *radiates heat at sunset*, and the air is rapidly cooled down by contact; this condensation causes a *motion in the air*, called the evening breeze.

504 *Why do south winds often bring rain?*

Because, coming from the torrid zone, they are much *heated*, and *absorb water very plentifully* as they pass over the ocean.

505 *How does this account for the rainy character of south winds?*

As soon as they reach a cold climate they become chilled, and can no longer hold all their vapor in suspension; in consequence of which some of it is deposited as rain.

506 *Why are dry winds in the spring months desirable and advantageous for agricultural operations?*

They *dry the soil* saturated with the moisture of winter, *break up the heavy clods*, and fit the land for the *seed* committed to it.

507 *Why is a fine clear day sometimes overcast in a few minutes?*

Because some *sudden change of temperature* has condensed the vapor of the air *into clouds.*

508 *Why are clouds sometimes dissipated very suddenly?*

Because some *dry wind* (blowing over the clouds) *imbibes their moisture*, and carries it off in invisible vapor.

509 *Why does wind sometimes bring rain, and sometimes fine weather?*

If the wind be *colder than the clouds*, it will condense their vapor into *rain;* but if the wind *is warmer than the clouds*, it will *dissolve* them and cause them to disappear.

510 *What is a hurricane?*

The hurricane is a *remarkable storm wind*, peculiar to certain portions of the world. It rarely takes its rise beyond the tropics, and it is the only storm to dread within the region of the trade-winds.

511 *How are hurricanes especially distinguished from other kinds of tempests?*

By their *extent*, *irresistible power*, and the *sudden changes* that occur in the *direction* of the wind.

512 *Do any particular portions of the tropics appear to be especially visited with hurricanes?*

In the northern hemisphere, the hurricane most frequently occurs in the regions of the *West Indies;* in the southern hemisphere, it occurs in the neighborhood of the *Mauritius.*

513 *Do the hurricanes occur at particular seasons?*

The West Indian occur from *August to October;* the Mauritian from *February to April.*

514 *What have recent investigations shown the hurricanes to be?*

Extensive storms of wind, which *revolve round an axis* either upright or inclined to the horizon; while at the same time the body of the storm has a *progressive motion* over the surface of the ocean.

515 *Illustrate more clearly the manner in which a hurricane moves?*

It is the nature of a hurricane to travel *round and round* as well as *forward,* much as a corkscrew travels through a cork, only the circles are all *flat,* and described by a rotatory wind upon the surface of the water.

516 *In what direction would a ship revolving in the circles of a hurricane find the wind?*

As the ship revolved, she would in turn find the wind blowing from *every point of the compass.*

517 *What is known concerning the distance travelled by hurricanes?*

The distance traversed by these terrible tempests is immense. The great gale of August, 1830, which occurred at St. Thomas on the 12th, reached the Banks of Newfoundland on the 19th, having travelled more than *three thousand nautical miles in seven days;* the track of the Cuba hurricane of 1844 was but little inferior in length.

518 *What is known of their progressive and rotary velocity?*

Their progressive velocity is from *seventeen to forty miles per hour;* but distinct from the *progressive* velocity is the rotary, which increases from the exterior boundary to the centre of the storm, near which point the force of the tempest is greatest, the wind sometimes blowing at the rate of *one hundred miles per hour.*

519 *How great is the breadth of the hurricane?*

The surface simultaneously swept by these tremendous whirlwinds is a vast circle varying from *one hundred to five hundred miles* in diameter.

520 *How great is the surface over which they prevail?*

Mr. Redfield, of New York, has estimated the great Cuba hurricane of 1844 to have been not less than *eight hundred miles* in breadth, and the area over which it prevailed during its whole length was computed to be *two million four hundred thousand square miles*—an extent of surface equal to two-thirds of that of all Europe.

521 *What curious fact have mariners noticed when in the centre or vortex of the hurricane?*

An awful *calm* prevails, described as the *lull* of the tempest, in which it seems to have rested only to gather strength for greater efforts.

522 *In what respect does a tornado differ from a hurricane?*

Tornadoes may be regarded as hurricanes, differing chiefly in respect to their *continuance* and *extent.*

523 *How long do they usually last?*

From *fifteen to seventy seconds.*

524 *What is their extent?*

Their breadth varies from a *few rods to several hundred yards*, and the length of their course rarely exceeds *twenty miles.*

525 *What phenomena generally attend them?*

The tornado is generally *preceded by a calm and sultry state of the atmosphere*, when suddenly the whirlwind appears, *prostrating everything* before it. Tornadoes are usually accompanied with thunder and lightning, and sometimes showers of hail.

526 *What is supposed to be the origin of tornadoes?*

They are supposed to be generally produced by the *lateral action* of an *opposing* wind, or the influence of a brisk gale upon a portion of the atmosphere in repose.

527 *How are the eddies or whirlpools produced which occur in water, and which in their formation resemble some tornadoes?*

Eddies or whirlpools are most frequently formed in water when *two streams* flowing unequally meet. They may be seen at the junction of two brooks or rivers.

528 *How are the whirlwinds which we frequently see at the corners of streets in cities produced?*

They are caused by a *gust of wind* sweeping round a corner of a building, and striking the calm air beyond it.

529 *What is a waterspout?*

A waterspout is a *whirlwind over the surface of water*, and differs from a whirlwind on land in the fact that water is subjected to the action of the wind, instead of objects on the surface of the earth.

530 *Why does wind generally feel cold?*

Because a *constantly-changing surface* comes in contact with our body to draw off its heat.

531 *What are the effects of wind noticed in the Arctic regions?*

Arctic explorers inform us that in those regions, when the thermometer ranges from 40° to 60° below zero, the cold of the external air is *easily endurable*, provided the air is *calm* and the *individual exercises freely*; but if a wind arises at this temperature, the *severity* of the cold becomes *too great* for *human endurance*.

532 *If the winds should cease to blow over the ocean, what would be the effect?*

The water would undoubtedly *become stagnant*. Tempests and hurricanes also exercise a beneficial effect by agitating and purifying the atmosphere, and sweeping from it the seeds of pestilence and contagion.

533 *What are clouds?*

Moisture *evaporated from the earth*, and again partially *condensed* in the upper regions of the air.

534 *What is the difference between a fog and a cloud?*

Clouds and fogs differ only in one respect. *Clouds* are *elevated above our heads*, but *fogs come in contact with the surface of the earth*.

535 *Why are clouds higher on a fine day?*

Because they are *lighter* and *more buoyant*.

536 *Why are clouds lighter on a fine day?*

1. Because the vapor of the clouds is *less condensed*; and

2. The *air itself* (on a fine day) retains much of its vapor in an *invisible* form.

537 *Why do clouds float so readily in the air?*

Because they are composed of *very minute globules* (called vesicles), which (being lighter than air) float like *soap-bubbles*.

538 *Are all clouds alike?*

No; they vary greatly in *density*, *height*, and *color*.

539 *What is the chief cause of fog and clouds?*

During the daily process of evaporation from the surface of the earth, warm, *humid currents* of air are continually *ascending;* the higher they ascend, the colder is the atmosphere into which they enter; and, as they continue to rise, a point will at length be attained where, in union with the colder air, their original humidity can no longer be retained: a cloud will then appear, which increases in bulk with the upward progress of the current into colder regions.

540 *How do changes in the wind produce clouds?*

If a *cold current of wind* blows suddenly over any region, it *condenses* the invisible vapor of the air into *cloud* or *rain;* but if a *warm current of wind* blows over any region, it *disperses* the clouds by *absorbing their vapor*.

541 *What distance are the clouds from the earth?*

Some *thin*, *light clouds* are elevated above the highest mountain-top; some *heavy* ones touch the steeples, trees, and even the earth; but the *average* height is between *one and two miles*.

Streaky, curling clouds, like hair, are often five or six miles high.

542 *What is the size of the clouds?*

Some clouds are *many square miles in surface*, and above *a mile in thickness;* while others are only a *few yards or inches*.

543 *How can persons ascertain the thickness of a cloud?*

As the *tops* of high mountains are generally above the clouds, travellers may pass *quite through* them into a clear blue firmament, when the clouds will be seen *beneath their feet.*

544 *Why do clouds, when not continuous over the whole surface of the sky, appear jagged, rough, and uneven?*

The *rays of the sun*, falling upon different surfaces at different angles, *melt away* one set of elevations, and *create* another set of depressions; the heat also which is liberated from below in the process of condensation, the currents of warm air escaping from the earth, and of cold air descending from above, all tend to keep the clouds in a state of agitation, upheaval, and depression. Under their various influences the masses of vapor composing the clouds are caused to assume all manner of grotesque and fanciful shapes.

545 *What effect have winds on the shape of clouds?*

They sometimes *absorb them entirely;* sometimes *increase their volume and density;* and sometimes *change the position of their parts.*

546 *How can winds absorb clouds altogether?*

Warm, dry winds will convert the substance of clouds into *invisible vapor*, which they will carry away in their own current.

547 *How can winds increase the bulk and density of clouds?*

Cold currents of wind will condense the *invisible vapor* of the air, and *add it to the clouds* with which they come in contact.

548 *Why is not the color of clouds always alike?*

Because their *size*, *density*, and *situation* in regard to the sun are perpetually varying, so that sometimes *one* color is reflected and sometimes *another*.

549 *Why do the clouds after sunset about the western horizon often exhibit a beautiful crimson appearance?*

Because the red rays, of which the sun's light is in part composed, are less refrangible than any of the other colors. In consequence of this, they are not bent out of their course so much as the blue and yellow rays, and are the last to disappear.

For the same reason they are the first to appear in *the morning when the sun rises, and impart to the morning clouds red or crimson colors.*

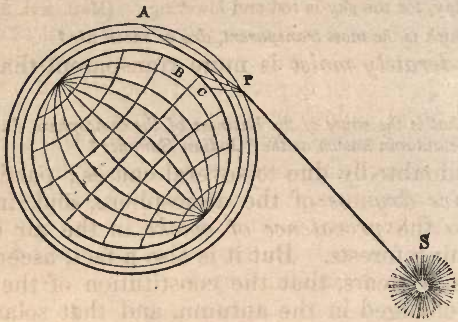


Fig. 19.

Let us suppose, as in *fig.* 19, a ray of light, proceeding from the sun, S, to enter the earth's atmosphere at the point P. The red rays, which compose in part the solar beam, being the least refrangible, or the least deviated from their course, will reach the eye of a spectator at the point A; while the yellow and blue rays, being refracted to a greater degree, will reach the surface of the earth at the intermediate points B and C. They will, consequently, be quite invisible from the point A.

550 *What is meant by being "less refrangible?"*

Being *less able to be bent.* Blue and yellow rays are more easily bent *below the horizon* through the action of the atmosphere, but red rays are not so much *bent down*, and therefore we see them later in the evening.

551 *What is the cause of a red sunset?*

The vapor of the air not being *actually condensed into clouds*, but only on the *point of being condensed.*

In the same manner, if light be transmitted through steam mingled with air, and therefore on the verge of condensation, it assumes a deep orange or red color.

552 *Why is a red and lowering sky at sunrise an indication of a wet day?*

The red and lowering appearance of the morning sky, which indicates foul weather, probably depends upon such an *excess of vapor* being present in the whole atmosphere that clouds are actually *forming in the* *higher regions*, or upon the point of condensation, which the rising sun cannot disperse.

Hence our Lord's observation—"In the morning ye say, It will be foul weather to-day, for the sky is red and lowering." (Matt. xvi. 3.)

553 *Which is the most transparent, dry or moist air?*

Air *moderately moist* is more transparent than very dry air.

554 *What is the cause of the haziness of the atmosphere during that portion of the autumn known as the "Indian Summer?"*

It is undoubtedly due to several causes; partially to an *excessive dryness* of the atmosphere, and, in some degree, to the *prevalence of smoke* in the air arising from burning forests. But it is also a fact, ascertained within a few years, that the constitution of the atmosphere is changed in the autumn, and that solar light at that season has less chemical influence than at any other portion of the year.

555 *Why does the sun seen through a fog appear red?*

Because the red rays of light have a *greater power* to pass through a *thick, dense atmosphere* than any of the other colored rays.

556 *Why does vapor sometimes form into clouds, and sometimes rest upon the earth as mist or fog?*

This depends on the *temperature* of the air. When the *surface of the earth* is *warmer than the lower air*, the vapor of the earth (being condensed by the chill air) becomes *mist or fog*. But when the *lower air* is *warmer than the earth*, the vapor *rises through the air*, and becomes cloud.

557 *Why do clouds often hover around mountain peaks, when the atmosphere elsewhere is clear and free from clouds?*

It is caused by the wind impelling up the sides of the mountains the *warm humid air of the valleys*, which in its ascent gradually becomes condensed by the cold, and its excess of moisture becomes visible, and appears as a cloud.

558 *Why are windows at night often covered with thick mist, and the frames wet with standing water?*

Because the temperature of the *external air* always *falls* at sunset, and *chills* the *window-glass* with which it comes in contact.

559 *How does this account for the mist and water on a window?*

As the warm vapor of the room *touches* the *cold glass* it is *chilled* and *condensed* into *mist*, and the mist (collecting into drops) *rolls down* the window-frame in little streams of water.

560 *Does the glass of a window cool down more rapidly than the air of the room itself?*

Yes; because the air is *kept warm by fires* and by the *animal heat* of the people in the room; in consequence of which the air of a room suffers *very little* diminution of heat from the setting of the sun.

561 *Whence arises the vapor of a room?*

The air of the room always contains vapor; vapor also arises from the breath and insensible perspiration of the inmates, from cooking and the evaporation of water.

562 *What is meant by "the insensible perspiration?"*

From every part of the human body an *insensible* and *invisible* perspiration issues all night and day, not only in the hot weather of summer, but also in the coldest days of winter.

563 *If the perspiration be both insensible and invisible, how is it known that there is any such perspiration?*

If you put your naked arm into a *clean*, *dry glass tube*, the perspiration will *condense* on the glass like mist.

564 *Why is a tumbler of cold water made quite dull with mist, when brought into a warm room?*

Because the *hot vapor* of the room is *condensed* upon the cold tumbler, with which it comes in contact, and changes its invisible and gaseous form into that of dew.

565 *Why does breathing on a glass make it quite dull?*

Because the cold glass condenses the invisible vapor contained in warm breath, and converts it into dew.

566 *Why are the walls of a house covered with damp in a sudden thaw?*

Because the walls (being thick) cannot *change* their *temperature* as fast as the air; in consequence of which they *retain* their *cold* after the thaw has set in.

567 *How does "retaining their cold" account for their being so wet?*

As the vapor of the warm air touches the cold walls, it is *chilled* and *condensed* into *water*, which either sticks to the walls or trickles down in little streams.

568 *Why is our breath visible in winter, and not in summer?*

Because the intense cold condenses its moisture into *visible vapor*, but in *summer* the air is not cold enough to do so.

569 *Why are our hair and the brim of our hat often covered with little drops of pearly dew in winter-time?*

Because the vapor of the breath condenses as it comes in contact with our cold hair or hat, and hangs there in little dew-drops.

570 *What are fogs?*

Fogs are *visible vapors* that float in the atmosphere near the surface of the earth.

571 *What is the cause of fogs?*

They originate in the *same causes as rain*—the union of a cool body of air with one that is warm and humid; when the precipitation of moisture is slight, fogs are produced; when it is copious, rains are the result.

572 *What distinction is to be made between a mist and a fog?*

Mist is generally considered to be a *fine rain*, while *fog* is *vapor* not sufficiently condensed to allow of its precipitation in drops.

The term mist is also generally applied to *vapors* condensed on *marshes*, *rivers*, and *lakes*, while the name fog is often applied to *vapors* condensed on *land*, especially if those vapors are laden with smoke.

573 *Why does not the fog become dew?*

Because the chill of the air is so *rapid* that vapor is condensed *faster* than it can be *deposited*, and covering the earth in a fog) prevents any further *radiation of heat* from the earth.

574 *When the earth can no longer radiate heat upwards, does it continue to condense the vapor of the air?*

No; the air (in contact with the earth) becomes about equal in *temperature* with the surface of the earth itself; for which reason the fog is not *condensed* into *dew*, but remains *floating* above the *earth* as a thick cloud.

575 *This fog seems to rise higher and higher, and yet remains quite as dense below as at first: explain the cause of this?*

The air resting on the *earth* is first chilled, and *chills* the air resting on *it;* the air which touches this *new layer* of fog being *also* condensed, layer is added to layer; and thus the fog seems to be *rising*, when (in fact) it is only *deepening.*

576 *Why are there not fogs every night?*

Because the air will always hold in solution a certain quantity of vapor (which varies according to its temperature); and, when the air is not *saturated*, it may be cooled without parting with its vapor.

577 *When do fogs occur at night?*

When the air is saturated with *vapor* during the day. When this is the case, it deposits some of its superabundant moisture in the form of dew or fog as soon as its capacity for holding vapor is lessened by the *cold night.*

578 *Why is there very often a fog over marshes and rivers at night-time?*

Because the air of marshes is almost always near *saturation;* and therefore the least depression of *temperature* will compel it to relinquish some of its moisture in the form of dew or fog.

579 *Why does vapor sometimes form into clouds, and sometimes rest upon the earth as mist or fog?*

This depends on the *temperature* of the air. When the *surface of the earth* is *warmer than the air*, the vapor of the earth (being condensed by the chill air) becomes *mist* or *fog.* But, when the *air* is *warmer than the earth*, the vapor *rises through the air*, and becomes cloud.

580 *If cold air produces fog, why is it not foggy on a frosty morning?*

1. Because *less vapor* is formed on a *frosty day;*

and 2. The vapor is *frozen* upon the *ground* before it can rise from the earth, and becomes *hoar-frost.*

581 *What is rain?*

Rain is the vapor of the clouds or air *condensed* and precipitated to the earth.

582 *In what manner is the vapor of the air condensed so as to form rain?*

When *two or more volumes* of humid air differing considerably in temperature *unite*, the several portions in union are incapable of absorbing the same amount of moisture that each could retain if they had not united. The excess of moisture, if very great, is precipitated as rain; if in slight amount, it appears as clouds, fogs, or mists.

583 *Upon what law does this condensation of vapor and formation of rain depend?*

Upon the law that the *capacity* of the air for *moisture decreases* in a greater ratio than the temperature.

584 *Why does rain fall in drops?*

Because the vapory particles in their descent *attract each other;* and those which are sufficiently near *unite* and form into drops.

The size of the rain-drop is increased according to the *rapidity* with which the vapors are condensed.

585 *Why does not the cold of night always cause rain?*

Because the air is not always near saturation; and unless this be the case, it will be able to hold its vapor in solution, even after it is condensed by the chilly night.

586 *Why does a passing cloud often drop rain?*

Because the cloud (travelling about on the wind) comes into contact with *something that chills it;* and its vapor being condensed, *falls to the earth* as *rain.*

587 *Can the air absorb moisture at all temperatures, and retain it in an invisible state?*

It can; and this power of the air is termed its *capacity of absorption.*

588 *How much moisture can a volume of air at 32° F. absorb?*

An amount equal to the *hundred and sixtieth part of its own weight.*

589 *How does the capacity of air for moisture increase with the temperature?*

For every 27 additional degrees of heat, the quantity of moisture it can absorb at 32° is doubled. Thus a body of air at 32° F. absorbs the 160th part of its own weight; at 59° F. the 80th; at 86° F. the 40th; at 113° F. the 20th part of its own moisture. It follows from this that, while the temperature advances in an arithmetical series, the capacity is accelerated in geometrical series.

590 *In what situations is the air always saturated?*

Over the *ocean* and upon the *adjacent coasts.*

591 *Where is the absolute humidity of the atmosphere the greatest?*

In the *tropics*, where the temperature of the air, and its consequent capacity for moisture, is the greatest.

592 *What is snow?*

The condensed vapor of the air *frozen* and precipitated to the earth.

593 *What is the cause of snow?*

When the air is nearly saturated with vapor, and is acted on by a current of air *below the freezing point*, some of the vapor is condensed, and frozen into snow.

A few years ago, some fishermen (who wintered at Nova Zembla), after they had been shut up in a hut for several days, *opened the window*, and the cold external air rushing in, instantly condensed the air of the hut, and its vapor fell on the floor *in a shower of snow.*

594 *What is the cause of sleet?*

When flakes of snow (in their descent) pass through a bed of air *above the freezing point*, they partially melt, and fall to the earth as half-melted snow, or sleet.

595 *How does snow prove beneficial to the earth in the cold season?*

It keeps the surface of the earth *warm*, protects vegetation to a considerable extent from the cold, and acts as a *fertilizer.*

596 *Does snow keep the earth warm?*

Yes, because it is a very *bad conductor;* in consequence of which, when the earth is covered with snow, its temperature very rarely descends *below the freezing point*, even when the air is fifteen or twenty degrees colder.

597 *Why is snow a bad conductor of heat and cold?*

Because *air* is confined among the crystals, and *air* is a very *bad* conductor; when, therefore, the earth is covered with snow, it cannot throw off its heat by radiation.

598 *Why is there no snow in summer-time?*

Because the *heat of the air* adjacent to the earth melts it in its descent, and prevents it from reaching the surface of the earth.

599 *Why is snow white?*

Because it is formed of an infinite number of very minute crystals and prisms, which reflect all the colors of the rays of light from different points, and these colors, *uniting* before they meet the eye, cause snow to appear white.

The same answer applies to salt, loaf-sugar, etc.

600 *Under what circumstances does snow fall in large flakes, and when in small?*

The largest flakes are formed when the air *abounds with vapor*, and the temperature is about 32° F.; but as the moisture diminishes, and the cold increases, the snow becomes finer.

601 *What is the snow flake composed of?*

Regular and symmetrical crystals, having a great diversity of forms.

602 *Do we see the same crystals in ice?*

They exist in ice, but are so *blended* together that their *symmetry is lost* in the compact mass.

603 *How much more bulky is snow than water?*

The bulk of recently-fallen snow is *ten or twelve times greater* than that of the water obtained by melting it.

604 *Does snow ever occur of any other appearance than white?*

Yes; in the Arctic regions and on some mountains it is *red*, and occasionally *green.*

605 *What is the cause of these appearances?*

These singular hues are occasioned by little *microscopic plants*, which germinate and live in the snow. They consist of little globules from $\frac{1}{1000}$ of an inch to $\frac{1}{3000}$ of an inch. Each globule is divided into seven or eight cells filled with a liquid, which gives a color to the snow, and is sometimes green and sometimes red.

606 *What is hail?*

Rain, which has passed in its descent *through some cold bed of air*, and has been frozen into drops of ice.

607 *What makes one bed of air colder than another?*

It is frequently caused by *electricity unequally distributed* in the air.

608 *How can electricity make air cold?*

Air, when *electrified*, is *expanded*, and *expansion* produces *cold.*

609 *Why does hail fall generally in summer and autumn?*

Because the air is *more highly electrified* in summer and autumn than in winter and spring; and the vapors in summer and autumn (being rarefied) ascend to more elevated regions, which are *colder* than those nearer the earth.

610 *Is the occurrence and formation of hail clearly understood?*

It is *not;* much information exists upon the subject, but *no theory* has yet been formed which *satisfactorily accounts* for all the facts which have been observed.

611 *What are meteorites?*

Meteorites are *solid*, *luminous bodies*, which from time to time visit the earth, moving with immense velocity, and remaining visible but for a few moments. They are generally accompanied by a luminous train, and during their progress explosions are often heard.

612 *What is an aerolite?*

The term aerolite is given to those *stony masses* of matter which are sometimes seen to fall from the atmosphere.

It is derived from the Greek words, αερ (atmosphere), and λιθος (a stone). A meteor is distinguished from an aerolite by the fact that it bursts in the atmosphere, but leaves no residuum except a vapor-like smoke; while the aerolite, which is supposed to be a fragment of a meteor, comes to the ground.

613 *What is the weight of those aerolites which have been known to fall from the atmosphere?*

Their weights vary from a *few ounces* to *several hundred pounds*, or even *tons.*

614 *At what height in the atmosphere are meteors supposed to appear?*

Their height above the earth has been estimated to vary from *eighteen to eighty miles.*

615 *With what velocity do they move?*

The velocity of these bodies is somewhat more than *three hundred miles per minute*, though one meteor of immense size, which is supposed to have passed within *twenty-five miles* of the earth, moved at the rate of *twelve hundred miles per minute.*

616 *What is the value of such estimates?*

Owing to the short time the meteor is visible and its great velocity, accurate observations cannot be made upon it; and all estimates respecting their distance, size, etc., must be considered as only *approximations to the truth.*

617 *What is the general appearance of aerolites?*

Most of them are covered with a *black shining crust*, as if the body had been coated with pitch. When broken their color is ash-grey, inclining to black.

Very many of the meteorites which have fallen at different times and in different parts of the globe, resemble each other so closely, that they would seem to have been broken from the same piece or mass of matter.

618 *What is their composition?*

Great numbers of aerolites have been analysed, and found to contain *nineteen or twenty different elementary substances.* But for the most part they consist of *malleable iron and nickel.*

619 *Do the aerolites resemble in composition any other bodies upon the surface of the earth?*

They do *not:* malleable iron is *rarely* if ever found in *terrestrial substances;* and metallic nickel does not occur upon the surface of the earth naturally.

620 *What is peculiar to the composition of meteoric iron?*

It has a highly *crystalline arrangement*, so peculiar that it is especially distinguished by it. This arrangement of its particles enables us to decide upon the meteoric origin of masses of iron which are occasionally found scattered up and down the surface of the earth.

621 *Where have such masses been found?*

In the *south of Africa*, in *Mexico*, *Siberia*, and on the *route* overland to California. Some of these masses are of immense weight, and undoubtedly fell from the atmosphere.

622 *How are meteorites supposed to originate?*

Four hypotheses have been advanced to account for the origin of these extraordinary bodies: 1. That they are thrown up from *terrestrial volcanoes.* 2. That they are produced in the atmosphere from *vapors and gases* exhaled from the earth. 3. That they are thrown from *lunar volcanoes.* 4. That they are of the *same nature as the planets*, either derived from them, or existing independently.

623 *Which of these hypotheses is regarded as most probable?*

The *fourth* most fully explains the facts connected with the appearance of meteorites, and the *third* likewise has some *strong evidence* in its favor.

624 *In what respect do shooting stars differ from meteors?*

Their altitude and velocity are *greater*, they are far *more numerous* and *frequent*, and are *unaccompanied* by any *sound* or *explosion.* Their brilliancy is also much *inferior* to that of the *meteor;* and no portion of their substance is ever known to have reached the earth.

625 *What do we know concerning their altitude?*

Owing to their great number and frequency of occurrence, many careful observations have been made upon them; their altitude is supposed to vary from six to four hundred and sixty miles, the greatest number appearing at a height of *about seventy miles.*

626 *What is their supposed velocity?*

It is supposed to range from *sixty to fifteen hundred miles per minute.*

627 *Are meteors and shooting stars at all times equally abundant?*

They are *not;* some may be seen *every clear night*, but they appear to return at *certain periodical epochs*, when they descend literally in showers.

628 *What are the periods when they may be noticed most abundantly?*

On the *9th and 10th of August*, and the *12th and 13th of November.*

They have also been noticed in unusual abundance on the 18th of October, the 6th and 7th of December, the 2d of January, the 23d and 24th of April, and from the 18th to the 20th of June.

629 *Do the shooting stars appear to emanate from any particular part of the heavens?*

The majority seem to start from a point in the constellation Perseus, and undoubtedly far beyond the limits of our atmosphere.

630 *What is the zodiacal light?*

It is a *singular luminous* appearance seen in the horizon before sunrise and after sunset, most conspicuously in the months of April and May.

Observations made during the year 1855 seem to conclusively prove that the appearance known as the "zodiacal light" is occasioned by a ring of nebulous matter encircling and pertaining to the earth.

CHAPTER VII.

THE PUMP AND BAROMETER.

631 *Why, when we suck up a liquid with a tube or straw, does the liquid rise to the mouth?*

One end of the tube being placed between the lips, the air is removed from the tube by the ordinary process of inhaling, when the *pressure of the atmosphere* compels the liquid to fill the space deserted by the air.

632 *Through how great a length of tube could we raise a liquid by suction?*

About *thirty-two feet.*

633 *Why can we not raise it above thirty-two feet?*

Because the *atmospheric pressure* will only support or balance a column of water or similar liquid of that height.

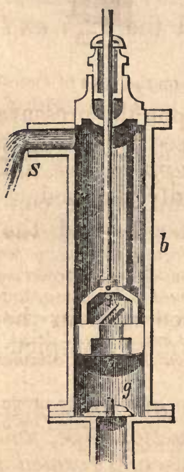


Fig. 20.

634 *How is the common pump constructed?*

The common pump consists of a *hollow tube*, the *lower part* of which, descending into the water, is called the *suction-pipe*, and the *upper part*, *b* (*Fig.* 20), the *barrel* or *cylinder;* of a *spout*, *s*, at the top of the cylinder; of an *air-tight piston*, which works up and down in the cylinder; and of two valves, both opening upwards, one of which, *g*, is placed at the top of the suction-pipe, and the other, *p*, in the piston.

635 *How does the common pump operate?*

When the piston is raised from the bottom of the cylinder, the air above it is *drawn up*, leaving a *vacuum* below the piston; the water in the well then rushes up through *the valve*, *g*, and fills the *cylinder;* the piston is then forced down, shutting the valve, *g*, and causing the water to rise through the piston-valve, *p;* the piston is then raised, closing its valve, and raising the water above it, which *flows out of the spout*, *s*.

636 *What is a valve?*

A valve, in general, is a contrivance by which water or other fluid, flowing through a tube or aperture, is allowed free passage in one direction, but is stopped in the other. Its structure is such, that, while the pressure of fluid on one side has a tendency to close it, the pressure on the other side has a tendency to open it.

Figs. 21, 22, and 23 represent the various forms of valves used in pumps, water-engines, etc.


Fig. 21.


Fig. 22.

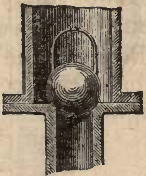


Fig. 23.

637 *How can water be raised by the common suction-pump?*

As the action of this pump depends upon the pressure of the atmosphere, water cannot be raised by it from a depth of *more than* 34 *feet below the upper valve*, and in practice a much shorter limit is usually assigned.

638 *A tinman of Seville, in Spain, ignorant of the principles of science, undertook to construct a suction-pump to raise water from a well sixty feet deep; when the machine was finished, he was confounded at discovering that it had no power to raise water at all, and enraged at his disappointment, while some one was working the pump, he struck the suction pipe with a hammer or axe so forcibly as to crack it, when, to his surprise and delight, the water almost immediately began to flow, and he found he had attained his purpose. How is this result to be accounted for?*

The explanation is as follows: *the air pressed in through the slit, or aperture of the suction-pipe*, and becoming mixed with the water in its ascent, *formed a compound fluid* far lighter than water alone, and therefore acted upon more readily by the atmospheric pressure; and thus produced the phenomenon described.

639 *How high can water be raised in the suction-pump by resorting to the expedient above described?*

About *fifty-five feet*, instead of thirty to thirty-four.

640 *To whom is the invention of the common pump attributed?*

To *Ctesibius*, an Athenian engineer, who lived at Alexandria, in Egypt, about the middle of the second century before the Christian era.

641 *When it is desired to raise water above thirty-four feet, as in fire-engines, etc., how is it accomplished?*

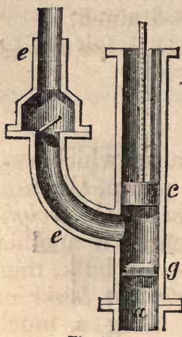


Fig. 24.

By means of the *forcing-pump.*

642 *In what manner is the forcing-pump constructed?*

In the forcing-pump atmospheric pressure plays but a small part. There is no valve in the piston *c* (*fig.* 24), but the water raised through the suction-pipe *a*, and the valve *g*, is forced by each depression of the piston up through the pipe *e e*, which is furnished with a valve to prevent the return of the fluid.

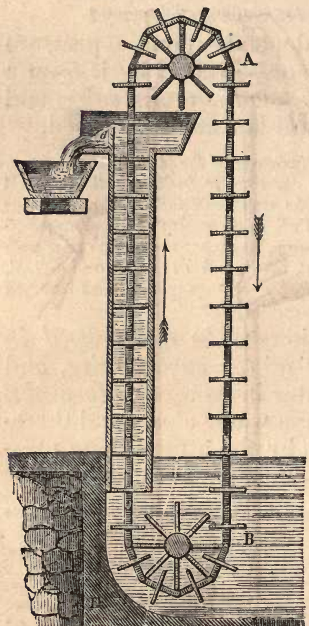


Fig. 25.

643 *What is a chain-pump?*

The chain-pump consists of a tube or cylinder, the lower part of which is immersed in a well or reservoir, and the upper part enters the bottom of a cistern into which the water is to be raised. A chain is carried round a wheel at the top, and is furnished at equal distances with movable bottoms, which fit water-tight in the tube. As the wheel revolves, they successively enter the tube, and carry the water up before them, which is discharged into the cistern at the top of the tube.

Fig. 25 represents the construction and arrangement of the chain-pump.

644 *Under what circumstances is the chain-pump generally employed?*

When the height through which the water is to be raised, is not very considerable, as in the case where the foundations of docks, &c., are to be drained.

645 *Who first ascertained and demonstrated the reason for the ascent of water in a tube by suction, and in the common pump?*

Torricelli, a pupil of Galileo.

646 *How was he led to his conclusions?*

He argued, that whatever be the cause which sustained a column of water in a common pump, *the measure of the power thus manifested must be the weight of the column of water;* and consequently, if another liquid be used, heavier or lighter, bulk for bulk, than water, *then the same force must sustain a lesser or greater column of such liquid.* By using a much heavier liquid, the column sustained would necessarily be much shorter, and the experiment in every way more manageable.

Torricelli verified his conclusions in the following manner:—He selected for his experiment mercury, the heaviest known liquid. As this is 13½ times heavier than water, bulk for bulk, it followed that, if the force imputed to a vacuum could sustain 33 feet of water, it would necessarily sustain 13½ times less, or about 30 inches, of mercury. Torricelli therefore made the following experiment, which has since become memorable in the history of science:—

He procured a glass tube (*Fig.* 26) more than 30 inches long, open at one end, and closed at the other. Filling this tube with mercury, and applying his finger to the open

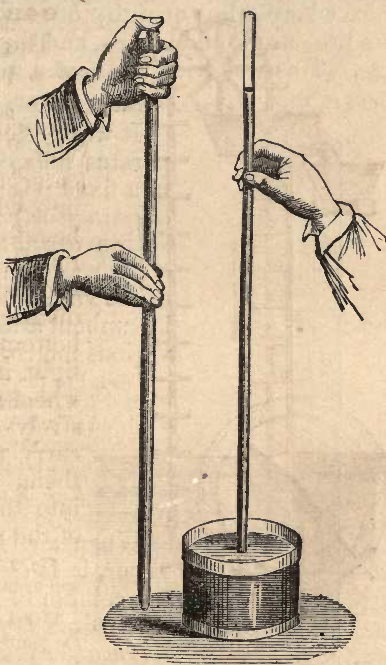


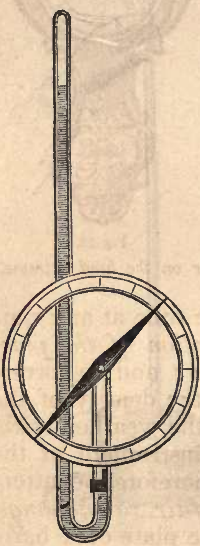
Fig. 26.

end, so as to prevent its escape, he inverted it, plunging the end into mercury contained in a vessel. On removing the finger, he observed that the mercury in the tube fell, but did not fall altogether into the cistern; it only subsided until its surface was at a height of about 30 inches above the surface of the mercury in the cistern. The result was what Torricelli expected, and he soon perceived the true cause of the phenomenon. The weight of the atmosphere acting upon the surface of the mercury in the vessel, supports the liquid in the tube, this last being protected from the pressure of the atmosphere by the closed end of the tube.

647 *How was the fact that the column of mercury was sustained by the pressure of the atmosphere further verified?*

By an experiment made by *Pascal*, in France. He argued, that if the cause which sustained the column in the tube was the weight of the atmosphere acting on the external surface of the mercury in the cistern, then, if the tube was transported to the top of a high mountain, where a less quantity of atmosphere was above it, the pressure would be less, and the length of the column less. This was tried and found to be the case.

648 *How did these experiments lead to the invention of the barometer?*



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It was noticed that when the apparatus above described was kept in a fixed position, the *height of the column fluctuated* from day to day within certain small limits. The effect was of course to be attributed to the variation in the weight of the incumbent atmosphere, arising from various meteorological causes.

This led to the use of the tube and cistern of mercury, arranged in the manner before described (*Fig.* 26), for determining the changes in the atmosphere, and consequently the character of the weather.

649 *Explain more fully in what manner the barometer can be used as a weather-glass?*

When air is *moist*, or filled with vapor, it is *lighter* than usual, and the column of mercury stands *low;* when air is *dry* and free from vapor, it is *heavier* than usual, and the mercury stands *high*. Thus the barometer (by showing the variations in the *weight of the air*) indicates the changes of the *weather also.*

Fig. 28.

650 *How is the common form of barometer, called the wheel-barometer, constructed?*

The barometer consists of a *bent tube*, filled with mercury, as represented in *Fig.* 27, the column being sustained by the pressure of the atmosphere upon the surface of the mercury in the shorter arm, the end of which is open. A small float of iron or glass rests upon the mercury in the shorter arm of the tube, and is suspended by a slender thread, which is passed round a wheel carrying an index. As the level of the mercury is altered, and the weight raised or lowered in the tube, the index moves; and as the divisions on the circumference of the circles within which it moves are much amplified, very slight changes are easily read off.

Fig. 27 represents the internal structure of the wheel-barometer, and *Fig.* 28 its external appearance, or casing, with a thermometer attached.

651 *Why is the ordinary use of the barometer on the land extremely limited and uncertain?*

The height of the mercury in the tube at any time must depend partially upon the *elevation of the place of observation above the level of the sea;* and no correct judgment can be formed relative to the density of the atmosphere as affecting the state of the weather, without reference to the situation of the instrument at the time of making the observation. Therefore, no attention ought to be paid to the words, "*fair, rain, changeable,*" etc., frequently engraved on the plate of a barometer, as they will be found no *certain* indications of the correspondence between the heights marked, and the state of the weather.

652 *What is the difference between a thermometer and a barometer?*

In a *thermometer* the mercury is *sealed up from the air;* and rises or falls as the varying *temperature* of the air expands or contracts it; but in a *barometer* the mercury is left *exposed* (or open) *to the air;* and rises or falls as the varying *weight* of the air presses upon the open column.

653 *Why is the tube of a barometer left open?*

That the air may *press upon it* freely; and, as this pressure varies, the mercury *rises or falls* in the tube.

654 *Why does the mercury in the barometer rise at the approach of fair weather?*

Because the air is becoming *more dry*, and the drier the air, and the more free it is from vapor, the greater the pressure.

655 *Why does the mercury sink at the approach of foul weather?*

Because the air is *laden with vapor* or *disturbed by wind.*

656 *Why does vapor in the air cause the mercury to sink?*

Because air containing vapor is *lighter than dry air;* and its pressure on the mercury is therefore less.

657 *Why will there be no rain if the air be very dry?*

Because *dry* air will *absorb moisture*, and not part with it in *rain.*

CHAPTER VIII.

PECULIARITIES OF CLIMATES.

658 *What do we mean by the term climate?*

By climate, we mean the condition of a place in relation to the various phenomena of the atmosphere, as temperature, moisture, etc. Thus, we speak of a warm or cold climate, a moist or dry climate, etc.

659 *What is meant by the mean daily temperature?*

The mean or average temperature of the day is found by observing the thermometer at fixed intervals of time during the twenty-four hours, and then *dividing the sum of the temperatures* by the *number of observations.*

660 *How is the mean annual temperature of a particular point ascertained?*

By taking the average of all the *mean daily temperatures throughout the year.*

661 *How does temperature vary with the latitude?*

The average annual temperature of the atmosphere *diminishes* from the *equator towards either pole.*

662 *Give examples of this variation?*

At the equator, in Brazil, the average annual temperature is 84° Fahrenheit's thermometer; at Calcutta, lat. 22° 35′ N., the annual temperature is 78° F; at Savannah, lat. 32° 5′ N., the annual temperature is 65° F.; at London, lat. 51° 31′ N., the annual temperature is 50° F.; at Melville Island, lat. 74° 47′ N., the mean annual temperature is 1° below zero.

663 *How does the temperature vary with the altitude above the earth's surface?*

Temperature *diminishes with the altitude.* As a general rule, a loss of heat occurs to the extent of one degree F. for every 343 feet of elevation.

664 *How does the gradual reduction of temperature as we ascend from the surface of the earth affect the moisture of the air?*

In every latitude there is a *point above the surface* of the earth where moisture, once frozen, *always remains congealed.*

665 *Why are the tops of very high mountains always covered with snow?*

Because, at the great elevation of their summit, the *temperature* of the atmosphere is so *low* that the congealed moisture which falls upon them *never melts.*

666 *What is a glacier?*

The glacier only exists upon mountains whose summits are covered with perpetual snow. The snow upon the higher parts becomes somewhat softened during the summer, and in the winter is again hardened nearly to ice. In the succeeding summer, the action of the sun, and the internal heat of the earth, detach large masses loaded with recently deposited snow into the neighboring valleys, where, being accumulated, and the crevices filled with snow or water which at last *hardens to ice*, they form huge seas of ice, or a *glacier;* in French, *mers-de-glace.*

667 *Do the glaciers continue to increase year by year?*

Very many of them do; and in Switzerland many valleys, once *fertile*, are now *filled with glaciers.* From the bottom of the glacier streams of water constantly issue, and it is from such sources that the rivers *Rhine* and *Rhone* of Europe *take their rise.*

668 *How are the gigantic icebergs formed which are found floating at some seasons in the Atlantic?*

They are portions of *great glaciers* formed in the northern regions, which become *detached* and float in the sea.

669 *How high are icebergs sometimes seen?*

Sometimes exceeding 300 *feet in height.*

670 *At what elevation above the surface of the earth, at the equator, will water remain frozen?*

At an elevation of about 15,000 *feet.*

671 *At what elevation in the straits of Magellan will water remain frozen?*

At about 4000 *feet.*

672 *What is the point where water remains frozen called?*

The line of *perpetual snow.*

673 *Why are not all places which lie under the same parallel of latitude of the same temperature?*

Because various *disturbing circumstances* tend to *vary* the mean temperature.

674 *What disturbing circumstances affect the temperature of particular situations?*

1. The *elevation* and *form* of the land;
2. The *proximity of the sea*;
3. *Mountains*, *swamps*, and *forests*;
4. The *nature* of the soil; and
5. The prevalence of *cold* or *warm winds*.

675 *What effect is produced on temperature by the configuration of lands?*

Islands and peninsulas are *warmer* than continents; *bays* and *inland seas* also tend to raise the mean temperature.

676 *What effect has the sea on temperature?*

In *warm climates* it tends to *diminish* the heat; in *cold climates* to *mitigate* the cold.

677 *What effect have mountains on temperature?*

Chains of mountains which ward off *cold* winds, *augment the temperature*; but mountains which ward off *south* and *west* winds, *lower* it.

678 *What effect has soil on temperature?*

A sandy soil, which is *dry*, is *warmer* than a marshy soil, which is *wet*, and subject to great evaporation.

679 *What is a natural soil?*

Natural soils are *merely decomposed parts of the subjacent rocks*, mixed with the decomposed portion of vegetable substances which have grown or fallen upon it, with some animal substances.

680 *What is the name given to the vegetable and animal products mixed with the mineral ingredients of a soil?*

Humus.

681 *What beneficial effect do loose stones and rocks have upon dry porous soils?*

They *retain moisture* in the soil by preventing the evaporation which would otherwise take place. In high lands they serve to condense fogs and low clouds, and thus add to the moisture of the subjacent soil.

682 *What countries are the most cloudy?*

Those where the temperature and winds are *most variable*, as Great Britain.

683 *What countries are the least cloudy?*

Those where the temperature and winds are *least variable*, as Egypt.

684 *Why are mountainous countries more rainy than flat ones?*

Because the air (striking against the sides of the mountains) is *carried up the inclined plane*, and brought in contact with the *cold air* of the higher regions; in consequence of which its vapor is *condensed* and deposited in rain.

685 *When is the quantity of moisture in the air greatest, and when least?*

It is greatest in the *summer months*, and least in the *winter*.

686 *In what part of the world does rain fall most abundantly?*

Near the *equator;* and the quantity of rain *decreases* as we approach the *poles*.

687 *How many inches of rain fall yearly at the city of Vera Cruz, Mexico?*

About *two hundred and seventy-eight inches.*

688 *How great a depth of rain, measured in inches, falls yearly in London?*

About *twenty-five inches*

689 *How do you account for the great amount of rain falling at Vera Cruz?*

Vera Cruz, situated within the tropics, is backed by *lofty mountains*, whose summits are covered with *perpetual snow;* against these the *hot*, *humid air* from the sea is driven by the trade-winds, *condensed*, and its excess of moisture is precipitated as rain.

690 *In what latitudes do the greatest number of rainy days occur?*

There are more rainy days in the *temperate zones* than in the tropics, although the yearly quantity of rain falling in the latter districts is much greater than in the former.

691 *About how many rainy days are there in a year in the northern parts of the United States?*

About *one hundred and thirty-four;* in the Southern States the number is somewhat less, being about one hundred and three.

692 *Why does it rain more frequently in the temperate zones than in the tropics?*

Because the temperate zone is a region of *variable winds*, and the temperature of the atmosphere changes often; while in the tropics the wind changes but rarely, and the temperature is very constant throughout a great part of the year.

693 *How is the amount of rain measured?*

By means of a *rain-gauge.*

694 *How is this constructed?*

The best form consists of a *cylindrical metal vessel* furnished with a float; the rain falling into the vessel *raises the float*, the stem of which is so *graduated* that the increase in depth can be very accurately measured.

695 *Why does it rain more upon the sea-coast than in the interior of a country?*

Because the air adjacent to the ocean contains more *moisture* than the air inland.

696 *What is the average yearly fall of rain in the tropics and temperate zones?*

The average yearly fall of rain in the tropics is *ninety-five inches;* in the temperate zone only *thirty-five.*

The greatest rain-fall, however, is precipitated in the shortest time. Ninety-five inches fall in eighty days on the equator, while at St. Petersburg the yearly rain-fall is but seventeen inches, spread over one hundred and sixty-nine days. Again, a tropical wet day is not continuously wet. The morning is clear; clouds form about ten o'clock; the rain begins at twelve, and pours till about half-past four; by sunset the clouds are gone, and the nights are invariably fine.

697 *In the tropics, how are the seasons divided?*

Into the *wet* or *rainy*, and the *dry* season.

698 *Are there some countries entirely destitute of rain?*

In some parts of *Egypt* it never rains; in Peru it rains *once*, perhaps, in a *man's lifetime.*

Upon the table-land of Mexico, in parts of Guatemala and California, for the same reason, rain is very rare. But the grandest rainless districts are those occupied by the great desert of Africa, extending eastward over portions of Arabia and Persia to a desert province of the Belooches—districts farther continued in the heart of Asia over the great desert of Gobi, the table-land of Thibet, and part of Mongolia. In all these are five or six millions of square miles of land that never taste a shower.

699 *Why are these countries destitute of rain?*

The cause of this scarcity is to be sought for in the *peculiar conformation of the country.*

In Peru, parallel to the coast, and at a short distance from the sea, is the lofty range of the Andes, the peaks of which are covered with perpetual snow and ice. The prevailing wind is an east wind, sweeping from the Atlantic to the Pacific across the continent of South America. As it approaches the west coast, it encounters this range of mountains, and becomes so cooled by them that it is forced to precipitate its moisture and passes on to the coast almost devoid of moisture. In Egypt and other desert countries, the dry sandy plains heat the atmosphere to such an extent that it absorbs moisture, and precipitates none.

700 *Are there some districts in which it may be said to always rain?*

In some portions of *Guiana* it rains for a great portion of the year. The fierce heat of the tropical sun fills the atmosphere with *vapor*, which returns to the earth again in constant showers, as the cool winds of the ocean flow in from the higher latitudes.

701 *How great a quantity of water is supposed to be annually precipitated as rain?*

The amount is calculated to exceed *seven hundred and sixty millions of tons*

702 *Was this whole amount raised by evaporation into the atmosphere?*

Certainly; the daily amount of water raised by evaporation from the sea alone amounts to no less than *one hundred and sixty-four cubic miles*, or about *sixty thousand cubic miles annually.*

703 *What is the daily amount of evaporation from the sea between the Cape of Good Hope and Calcutta?*

During the months of *October* and *November*, it is known to average three quarters of an inch daily from the whole surface.

704 *Is the climate of New England and the Northern United States drier than that of England and Central Europe?*

It is; and this fact exercises an *important influence* upon many professions and callings. Painters find that their work dries quicker in New England than in Central Europe. Cabinet-makers here are obliged to use thicker glue, and watchmakers animal instead of vegetable oil.

705 *Why will not pianofortes made in England or Germany answer for use in New England?*

Because the *difference* in the climate of these respective countries is so great, as respects *moisture*, that the foreign instruments shrink, and quickly become damaged.

706 *In what climates do hail-storms most frequently occur?*

In *temperate climates* most frequently, and rarely within the tropics.

707 *In what localities in the temperate zones do hail-storms occur most frequently?*

In the *vicinity of high mountains*, whose peaks are always covered with ice and snow. The south of France, which lies between the Alps and Pyrenees, is annually ravaged by hail; and the damage which it causes yearly to vineyards and standing crops, is estimated at upwards of nine millions of dollars.

708 *Do the general meteorological changes which take place almost daily, and which are designated as weather changes, occur in accordance with certain fixed laws?*

There is no reason to doubt that every change in the weather is in strict accordance with some *certain physical agencies*, which are fixed and certain in their operations.

709 *Why can we not, then, with certainty determine and foretell the character of the weather for any particular time?*

Because the laws which govern meteorological changes are as yet *imperfectly understood.*

710 *Is there any reason for supposing that the moon has any influence upon the weather?*

An examination of meteorological records, kept in different countries through many years, proves conclusively that the popular notions concerning the influence of the lunar phases on the weather have *no foundation* in any *well established theory*, and no correspondence with observed facts.

711 *Do meteorological records afford any support to the belief in the occurrence of rain at particular phases of the moon?*

There is some reason for supposing that rain falls more frequently about *four days before full moon*, and less frequently about four or five days before new moon, than at other parts of the month; but this cannot be considered as an established fact: in other respects the changes of the moon cannot be shown to have influenced in any way the production of rain.

712 *Does the bright moonlight in any way hasten the putrefaction of animal or vegetable substances?*

It is generally supposed to do so; but the fact is, that on bright, clear nights, when the moon shines brilliantly, *dew* is more *freely deposited* on these substances than at other times, and in this way putrefaction may be accelerated. With this the moon has no connexion.

713 *Is there any foundation for the belief that the appearance of the aurora borealis is followed by a change in the weather?*

Meteorological registers conclusively show that there is *no such connexion*, and that the appearance of the aurora is as often followed by fair weather as by foul.

714 *Is there any truth in the traditional notion that a long and violent storm usually accompanies the period of the equinoxes?*

The examination of weather-records for sixty-four years shows that *no particular day* can be pointed out in the month of September (when the "equinoctial storm" is said to occur) upon which there ever was, or ever will be, a so-called equinoctial storm. The fact, however, should not be concealed, that taking the average of the five days embracing the equinox for the period above stated, the amount of rain is greater than for any other five days, *by three per cent.*, throughout the month.

715 *Is there any reason for believing that cold and warm seasons alternate?*

Meteorological records, kept for eighty years at the observatory of Greenwich, England, seem to show that groups of *warm years alternate with cold ones* in such a way as to render it most probable that the mean annual temperatures rise and fall in a series of curves, corresponding to periods of *about fourteen years.*

716 *Is it probable that some animals and insects are able to foretell changes in the weather before man can perceive any indications of the same?*

Of this fact there appears to be *no doubt.* Some varieties of the land-snail only make their appearance *before a rain.* Some other varieties of land crustaceous animals change their color and appearance twenty-four hours before a rain.

717 *What curious fact has been noticed in respect to the leaves of trees indicating changes in the weather?*

For a light, short rain, some trees have been observed to *incline their leaves*, so as to *retain water;* but for a long rain, they are so doubled as to conduct the water away.

718 *What fact has also been noticed respecting the changes in springs previous to a rain?*

The water of springs has been observed to rise and flow out in greater volume *previous to a rain.*

Most, if not all, of the popular proverbs respecting changes in the weather, the influence of the moon, of frosts, auroras, and the like, when tested by observation, will be found to be unsupported by facts, and unworthy of the slightest credence.

719 *Why will there be no rain if the air be very cold?*

Because it is *so much condensed* that it has already parted with as much moisture as it can spare.

720 *Have heat and cold any effect on the barometer?*

No, not of themselves; but as *cold* weather is generally either *dry* or *rough*, with northerly winds, the mercury generally *rises* in cold weather; and as warm weather is often *moist*, or accompanied by southerly winds, which bring vapor with them, therefore the mercury often *sinks* in warm weather.

PART IV.

SOUND.

CHAPTER I.

ORIGIN AND TRANSMISSION OF SOUND.

721 *How is sound produced?*

Sound is heard when any sudden shock or impulse, *causing vibrations*, is given to the air, or any other body, which is in contact directly or indirectly with the *drum of the ear.*

722 *What is the drum or tympanum of the ear?*

A *thin membrane* which closes the aperture of the ear.

723 *How do the vibrations of the air, striking upon the drum of the ear, give us the sensation of sound?*

Behind the drum of the ear are various *cavities* and *tubes* in the bone which form the side of the head, in which the *minute fibres of the auditory nerve are distributed.* When the drum of the ear is made to vibrate freely by the action of the sonorous undulations of the external air, the vibrations are communicated by the action of minute bones, muscles, and fluids contained in the cavities of the ear, to the nerve, and from thence the impressions are conveyed to the brain.

Fig. 29 is a perspective magnified view of the interior of the ear. The several parts of the ear, and the progress of sound towards the nerve which communicates the sensation to the brain, may, however, be best illustrated by reference to *Fig.* 30:—

1. There is external to the head a wide-mouthed tube, or ear-trumpet, *a*, for catching and concentrating the waves of sound. It is movable in

Fig. 29.

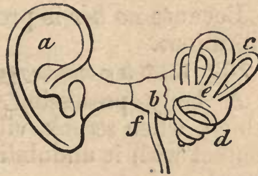


Fig. 30.

many animals, so that they can direct it to the place from which the sound comes.

2. The sound concentrated at the bottom of the ear-tube falls upon a membrane stretched across the channel, like the parchment of an ordinary drum, over the space called the *tympanum*, or *drum of the ear*, *b*, and causes the membrane to vibrate. That its motion may be free, the air contained within the drum has free communication with the external air by the open passage, *f*, called the *eustachian tube*, leading to the back of the mouth. A degree of deafness ensues when this tube is obstructed, as in a cold; and a crack, or sudden noise, with immediate return of natural hearing, is generally experienced when, in the effort of sneezing or otherwise, the obstruction is removed.

3. The vibrations of the membrane of the drum are conveyed further inwards, through the cavity of the drum, by a chain of four bones (not here represented on account of their minuteness), reaching from the centre of the membrane to the *oval door* or *window*, leading into the labyrinth *e*.

4. The labyrinth, or complex inner compartment of the ear, over which the nerve of hearing is spread as a lining, is full of watery fluid; and, therefore, by the law of fluid pressure, when the force of the moving membrane of the drum, acting through the chain of bones, is made to compress the water, the pressure is felt instantly over the whole cavity. The labyrinth consists of the *vestibule*, *e*, the three *semicircular canals*, *c*, imbedded in the hard bone, and a winding cavity, called the *cochlea*, *d*, like that of a snail-shell, in which fibres, stretched across like harp-strings, constitute the *lyra*. The separate uses of these various parts are not yet fully known. The membrane of the tympanum may be pierced, and the chain of bones may be broken, without entire loss of hearing.—Arnott.

724 *Is air necessary to the production of sound?*

No; but most sounds owe their origin to the vibrations of the air. Sound can be produced *under water*, and *all bodies* are, in fact, more or less fitted to *produce the sound vibrations;* in many cases air is neither the quickest nor the best conductor of sound.

725 *Upon what does the loudness of sound conveyed by air depend?*

Upon the *density* of the air?

726 *Why does a bell rung in a receiver exhausted of air fail to produce sound?*

Because *no air* is present to receive and transmit the vibrations.

727 *What is a sounding or sonorous body?*

A body possessing both hardness and elasticity, which, when struck, vibrates, and imparts to the air in contact with it undulations corresponding to its vibrations.

728 *Why has the peculiar kind of motion in bodies which gives rise to the sensation of sound, been termed vibration?*

Because a striking analogy may be traced between the tremulous agitation which takes place among the particles of a *sounding body* and the *oscillations* of a *pendulum.*

729 *How may the nature of sonorous vibrations be illustrated?*

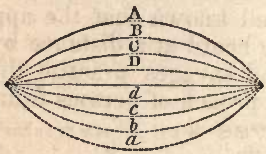


Fig. 31.

By noticing the visible motions which occur on striking or twitching a *tightly extended cord* or *wire.* Suppose such a cord, represented by the central line in *Fig.* 31, to be forcibly drawn out to A, and let go; it would immediately recover its original position by virtue of its elasticity; but when it reached the central point, it would have acquired so much momentum as would cause it to pass onward to *a;* thence it would vibrate back in the same manner to B, and back again to *b*, the extent of its vibration being gradually diminished by the resistance of the air, so that it would at length return to a state of rest.

730 *Why are copper and iron sonorous, and not lead?*

Copper and iron are *hard* and *elastic;* but as lead is neither hard nor elastic, it is *not sonorous.*

731 *Of what is bell-metal made?*

Of *copper* and *tin* in the following proportions:—In every five pounds of bell-metal there should be one pound of tin and four pounds of copper.

732 *Why is this mixture of tin and copper used for bell-metal?*

Because it is much *harder* and more *elastic* than any of the pure metals.

733 *Are solids capable of transmitting sounds?*

All solid bodies which possess elasticity have the power of propagating or transmitting sounds.

734 *What easy experiment illustrates the transmission of sound by solids?*

When a stick is held between the teeth at one extremity, and the other is placed in contact with a table, the scratch of a pin on the table may be heard with great distinctness, though both ears be stopped.

735 *Does the earth conduct sound?*

The earth often conducts sound, so as to render it sensible to the ear, when the air fails to do so. It is well known that the approach of a troop of horse can be heard at a distance by putting the ear to the ground, and savages practise this method of ascertaining the approach of persons from a great distance.

736 *What purpose is subserved by the body of a stringed instrument?*

The *string* of an *instrument*, when caused to vibrate, communicates the vibrations to the matter composing the body of the instrument and the surrounding air, and thus a *tone* or *musical note* is produced and rendered audible to the ear.

737 *How are aerial vibrations or pulses communicated?*

The air, encompassing sounding bodies on every side, conveys the sensation of sound in all directions; therefore the *aerial vibrations*, or, as they have been termed, "*pulses*," must be communicated successively and generally throughout the whole space within the limits of which they are capable of affecting the ear.

738 *To what have the sound vibrations or pulsations been compared?*

To the *waves* spreading in concentric circles over the smooth surface of water.

When a stone is thrown into water, the liquid waves are propagated not only directly forward from the centre, but if they encounter any obstruction, as from a floating body, they will bend their course round the sides of the obstacle, and spread out obliquely beyond it. So the undulations of air, if interrupted in their progress by a high wall or other similar impediment, will be continued over its summit and propagated on the opposite side of it.

739 *When a sonorous body is struck, do all the particles of which it is composed really move or vibrate?*

They do; and the body itself, no matter how compact and solid it may be, really changes its form with each vibration.

740 *How may the sound vibrations in a solid body be rendered visible?*

By many simple contrivances—as by a ball hung by a string to a bell, by pieces of paper placed on the strings of a violin, or by sand placed upon the sounding-board of a piano or any other stringed instrument.

741 *How fast does sound travel?*

About 13 miles in a minute, or 1142 feet in a second of time.

742 *Why is the flash of a gun fired at a distance seen long before the report is heard?*

Because light travels much faster than sound.

Light would go 480 times round the whole earth while sound is going its 13 miles.

743 *How is a knowledge of the velocity of sound made applicable to the measurement of distances?*

Suppose a flash of lightning to be perceived, and on counting the seconds that elapse before the thunder is heard, we find them to amount to $3\frac{1}{2}$; then as sound moves 1142 feet in a second, it will follow that the thunder-cloud must be distant $1142 \times 3\frac{1}{2} = 3997$ feet.

744 *Why do windows rattle when carts pass by a house?*

1. Because glass is *sonorous;* and the air communicates its vibrations to the glass, which echoes the same sound; and

2. The *window-frame* being *shaken*, contributes to the noise.

Window-frames are shaken, 1. By sound-waves striking against them. 2. By a vibratory motion communicated to them by the walls of the house.

745 *Why is the sound of a bell stopped by touching the bell with our finger?*

Because the weight of our finger *stops the vibrations* of the bell; and as soon as the bell *ceases to vibrate*, it ceases to make sound-waves in the air.

746 *Why does a split bell make a hoarse, disagreeable sound?*

Because the *split* of the bell causes a *double vibration;* and as the sound-waves *clash and jar*, they impede each other's motion, and produce discordant sounds.

747 *Why can persons, living a mile or two from town, hear the bells of the town churches sometimes and not at others?*

Because fogs, rain, and snow obstruct the passage of sound; but when the air is *cold and clear*, sound is propagated more easily.

748 *Why can we not hear sounds (as those of distant church bells) in rainy weather so well as in fine weather?*

Because the falling rain *interferes with the undulations of the sound-waves*, and breaks them up.

749 *Why can we not hear sounds (as those of distant church bells) in snowy weather so well as in fine weather?*

Because the falling snow *interferes* with the undulations of the *sound-waves*, and stops their progress.

750 *Why can we not hear sounds (such as those of distant clocks) so distinctly in a thick mist or haze as in a clear night?*

Because the air is not of uniform density when it is laden with mist; in consequence of which the sound waves are obstructed in their progress.

751 *Why do we hear sounds better by night than by day?*

1. Because night air is of *more uniform density*, and less liable to accidental currents; and

2. Night is more *still*, from the suspension of business and hum of men. Many sounds become perceptible during the night, which during the day are completely stifled, before they reach the ear, by the din and discordant noises of labor, business, and pleasure.

752 *Why is the air of more uniform density by night than it is by day?*

Because it is less liable to accidental currents; inasmuch as the breezes (created by the action of the sun's rays) generally *cease* during the night.

753 *How should partition walls be made, to prevent the voices in adjoining rooms from being heard?*

The space between the laths should be filled with *shavings* or *sawdust;* and then no sound would ever pass from one room to another.

754 *Why should shavings or sawdust prevent the transmission of sound from room to room?*

Because there would be *several different media* for the sound to pass through; and every change of medium diminishes the strength of the sound-waves.

755 *What solids are among the best conductors of sound?*

Iron and *glass;* sound is transmitted by them at the rate of 17,500 feet, or more than 3 miles in a second; after these rank copper, several different kinds of wood, silver, tin, &c.

CHAPTER II.

VOCAL AND MUSICAL SOUNDS.

756 *What is a musical sound?*

A musical sound is produced by regular undulations or vibrations—a succession of sounds following each other with perfect uniformity.

757 *How does a noise differ from a musical sound?*

A noise is the result of very irregular or disturbed undulations or vibrations.

758 *Do all persons hear sounds alike?*

The faculty of hearing depends upon the construction and sensibility of the ear, and as this differs in different individuals, it is certain that all persons will not hear sounds alike.

759 *What is meant by the terms concord and discord?*

When two tones or notes sounded together produce an agreeable effect on the ear, their combination is called a *musical concord;* when the effect is disagreeable, it is called a *discord.*

760 *What is the gamut or diatonic scale of music?*

It consists of *seven notes*, which are distinguished by the seven first letters of the alphabet, or by the seven syllables, *do*, *re*, *mi*, *fa*, *sol*, *la*, *si.*

761 *Why do flutes, etc., produce musical sounds?*

Because the breath of the performer causes the *air in the flute* to *vibrate;* and this vibration sets in motion the sound-waves of the air.

762 *Why does a fiddle-string give a musical sound?*

Because the bow drawn across the string *causes it to vibrate;* and this vibration of the string *sets in motion the sound-waves of the air*, and produces musical notes.

763 *Why does a drum sound?*

Because the parchment head of the drum *vibrates* from the blow of the drum-stick, and sets in motion the sound-waves of the air.

764 *Why do pianofortes produce musical sounds?*

Because each *key of the piano* (being struck with the finger) lifts up a little hammer which *knocks against a string;* and the vibration thus produced sets in motion the sound-waves of the air.

765 *Why is an instrument flat when the strings are unstrung?*

Because the vibrations are *too slow;* in consequence of which the sounds produced are not *shrill* or *sharp* enough.

766 *Why do birds alone, of animals, produce musical notes?*

Because they alone are gifted with a *vocal organization*, which enables them to producé musical notes. In other animals, the larynx is placed wholly at the upper end of the windpipe; but in birds it is separated, as it were, into two parts, one placed at each extremity.

767 *Why cannot birds be so correctly said to sing as to whistle?*

Because natural singing is an exclusive privilege of man.

768 *In the human system, what are the parts concerned in the production of speech and music?*

They are the *windpipe*, the *larynx*, and the *glottis.*

769 *What is the windpipe?*

The windpipe is merely a cartilaginous canal through which the air issues from the lungs.

770 *What is the larynx?*

The *larynx* is an *enlarged continuation of the windpipe*, formed, like it, of *cartilage* or *gristle*, *membrane*, and *muscle;* it is, however, more complicated, terminating above in two lateral membranes which approach near together, leaving an oblong, narrow opening, called the *glottis.*

771 *How is sound produced by the organs of voice?*

The *air* expired from the *lungs*, passes through the *windpipe* and out at the *larynx*, through the opening of the membrane called the *glottis.* The vibration of these membranes, caused by the passage of air, causes sound.

772 *How can the tones of the voice be made grave or acute?*

By varying the *tension* of these membranes and the *size* of the opening.

773 *What is the force exerted by the healthy chest in blowing?*

About *one pound on the inch of its surface;* that is to say, the chest can condense its contained air with that force, and can therefore blow through a tube the mouth of which is ten feet under the surface of water.

774 *What is the vocal action of coughing?*

In coughing the top of the windpipe or the glottis is *closed for an instant*, during which the chest is compressing and condensing its contained air; and on the glottis being opened, *a slight explosion*, as it were, of the compressed air takes place, and blows out any irritating matter that may be in the air-passages.

775 *Why does a popgun make a loud report when the paper bullet is discharged from it?*

Because the air confined between the paper bullet and the discharging rod is suddenly liberated, and strikes against the surrounding air; this makes a report in the same way as when any two *solids* (such as your hand and the table) come into collision.

776 *What is sneezing?*

Sneezing is a phenomenon resembling cough; only the chest empties itself at one effort, and chiefly through the *nose*, instead of through the *mouth*, as in coughing.

777 *What is laughing?*

Laughing consists of *quickly repeated expulsions of air* from the chest, the glottis being at the time in a condition to produce voice; but there is not between the expirations, as in coughing, a complete closure of the glottis.

778 *What is hiccough?*

Hiccough is the *stopping* of the commencement of a strong inspiration, by *a sudden closing* of the *glottis.*

779 *What is crying?*

Crying differs from laughing almost solely in the circumstance of the *intervals between the gusts or expirations* of air from the lungs *being longer.* Children laugh and cry in the same breath.

780 *Why, in straining to lift weights, or to make any powerful bodily effort, do we compress our breath?*

We shut up the air in the lungs in order to give *increased steadiness* and *firmness* to the body.

781 *When is a person suffocated?*

When the *windpipe becomes choked*, or the supply of air to the lungs is in any way cut off.

782 *Why do birds sing comparatively louder than man?*

Because the *strength* of the larynx, and of the muscles of the throat, in birds, is infinitely greater than in the human race. The loudest shout of man is but a feeble cry compared with that of the golden-eyed duck, the wild goose, or even the woodlark.

783 *How are winged insects generally found to produce sound?*

Generally they excite sonorous vibrations by the *fluttering of their wings* or other membranous parts of their structure.

784 *How do locusts produce sound?*

They are furnished with an *air-bladder*, or a species of *bagpipe*, placed under and rather behind their wings.

CHAPTER III.

REFLECTION OF SOUNDS.

785 *What is an echo?*

An echo is a reflection of sound.

786 *Will you explain the manner in which an echo is produced?*

When a wave or undulation of water strikes against a smooth surface, it is reflected, or turned back, and waves moving in an opposite direction are produced. The same thing takes place with a sound-wave of air: we hear first the sound proceeding directly from the sonorous body; then, if the sound-wave strikes against a proper surface, at a suitable distance, it is turned back, and we hear a repetition of the sound. This repetition we call an echo.

787 *Are echoes often heard at sea or on extensive plains?*

Very rarely; at sea or on an extensive plain there are no surfaces to reflect sound. It sometimes happens, however, that in these situations the clouds reflect sound.

788 *In what places do echoes most frequently occur?*

In caverns, large halls, valleys and mountainous passes, the windings of long passages, etc.

789 *Why are these places famous for echoes?*

Because the sound-waves cannot flow freely forward, but continually strike against opposing surfaces, and are turned back.

790 *What beautiful fiction existed among the ancients relative to the production of echo?*

They supposed that *Echo* was a *nymph* who dwelt concealed among the rocks, and who repeated the sounds she heard.

791 *At what distance must the body reflecting the sounds be situated in order to produce an echo?*

It is requisite that the reflecting body should be situated at such a distance from the source of sound, *that the interval between the perception of the original and reflected sounds may be sufficient to prevent them from being blended together.*

792 *When the sounds become thus blended together, what is the effect called?*

A *resonance*, and not an echo.

793 *Why do not the walls of a room of ordinary size produce an echo?*

Because the *reflecting surface* is so near the source of sound that the echo is *blended with the original sound;* and the two produce but *one impression* on the ear.

794 *Why do very large buildings (as cathedrals) often reverberate the voice of the speaker?*

Because the walls are *so far off from the speaker*, that the echo does not *get back in time* to blend with the original sound; and therefore *each* is heard separately.

795 *Why do some echoes repeat only one syllable?*

Because the echoing body is very *near.* The *farther* the echoing body is off, the *more sound* it will *reflect:* if, therefore, it be very *near*, it will repeat but one syl lable.

796 *Why does an echo sometimes repeat two or more syllables?*

Because the echoing body is *far off;* and therefore there is time for one reflection *to pass away* before *another* reaches the ear.

All the syllables must be *uttered* before the echo of the first syllable reaches the ear: if, therefore, a person repeats 7 syllables in 2 seconds of time, and hears them *all* echoed, the reflecting object is 1142 feet distant; because sound travels 1142 feet in a second, and the words take one second to *go to* the reflecting object, and one second to *return.*

797 *What must be the conditions of the reflecting surface in order to produce a perfect echo?*

The surface must be *smooth* and of some *regular form;* for the wave of sound rebounds, according to the same law as a wave of water or an elastic ball, *perpendicularly to the surface* if it fall perpendicularly, and if it fall *obliquely* on one side, it *departs with an equal degree of obliquity* on the other side.

798 *What must be the effect of an irregular surface?*

An *irregular surface* must break the *echo;* and if the irregularity be very considerable, there can be no distinct or audible reflection at all. For this reason an echo is much less perfect from the front of a house which has windows and doors, than from the plane end, or any plane wall of the same magnitude.

799 *Why have halls for music plane bare walls?*

Because the *hard plane walls reflect the sound regularly*, and increase the effect of the music.

800 *Why are halls for speaking, theatres, churches, etc., generally ornamented on the wall, and furnished with pillars, curtains, etc.*

Because the *ornaments*, *pillars*, *curtains*, etc., form *irregular surfaces*, which *break* up and *destroy* the echoes and resonances.

801 *Why is a thick curtain often placed behind a pulpit or speaking-desk?*

Because the *material absorbs the sound*, and by not reflecting it avoids the production of echoes and resonances.

If the room is not very large, a curtain behind the speaker impedes rather than assists his voice.

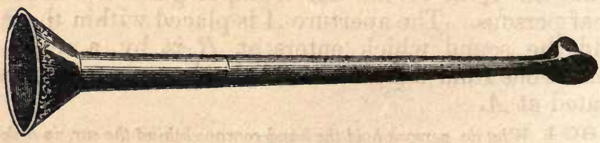


Fig. 32.

802 *What is a speaking trumpet?*

A speaking trumpet is a hollow tube, so constructed, that the rays of sound (proceeding from the mouth when applied to it), instead of diverging, and being scattered through the surrounding atmosphere, are reflected from the sides, and conducted forward in straight lines, thus giving great additional strength to the voice. The course of the rays of sound proceeding

Fig. 33.

from the mouth through this instrument, may be shown by *Fig.* 33. The trumpet being directed to any point, a collection of parallel rays of sound moves towards such point, and they reach the ear in much greater number than would the diverging rays which would proceed from a speaker without such an instrument.

803 *What is an ear trumpet?*

An ear trumpet, *Fig.* 34, is in form and application the reverse of a speaking trumpet, but in principle the same. The rays of sound proceeding from a speaker, more or less distant, enter the hearing trumpet, and are reflected in such a manner as to concentrate the sound upon the opening of the ear. *Fig.* 34 represents the form of the ear trumpet generally used by deaf persons. The aperture *A* is placed within the ear, and the sound which enters at *B* is, by a series of reflections from the interior of the instrument, concentrated at *A*.

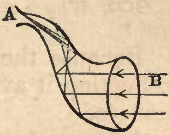


Fig 34.

804 *Why do persons hold the hand concave behind the ear, in order to hear more distinctly?*

Because the concave hand acts in some respects as an *ear trumpet*, and *reflects* the sound into the ear.

805 *Why does sound seem louder in a church or hall than on a plain?*

Because the sides of the building confine the sound-waves, and prevent their spreading; in consequence of which their *strength* is greatly increased.

806 *How can most of the stories in respect to the so-called "haunted houses" be explained?*

By reference to the principles which govern the reflection of sounds. Owing to a peculiar arrangement of reflecting walls and partitions, sounds produced by ordinary causes are often heard in certain localities at remote distances, in apparently the most unaccountable manner. Ignorant persons become alarmed, and their imagination connects the phenomenon with some supernatural cause.

PART V.

HEAT.

CHAPTER I.

NATURE AND ORIGIN OF HEAT.

807 *What is heat?*

In ordinary language the term heat expresses the sensation of warmth which we experience when any portion of our body comes in contact with a substance which is warmer than itself?

808 *Do we really know what heat is?*

We do not; we only know and study the effects which it produces on matter.

809 *To what cause have different philosophers attributed the phenomenon of heat?*

Some have supposed the phenomenon of heat to be merely a *species of motion* among the minute particles of bodies generally, as sound is motion of another kind among the same particles; others have supposed that heat arises from the *presence of a peculiar fluid or ethereal kind of matter.*

810 *Is it generally believed at the present time that heat is a material substance?*

It was believed formerly that heat was a kind of matter; but now it is generally considered that heat has no material existence.

811 *What great fact is opposed to the idea that heat has a separate material existence as a fluid?*

The fact that nature nowhere presents us, neither has art ever succeeded in showing us, heat alone in a separate state.

812 *Has heat any perceptible weight?*

No; if we balance a quantity of ice in a delicate scale, and then leave it to melt, the equilibrium will not be in the slightest degree disturbed. If we substitute for the ice boiling water or a red-hot iron, and leave this to cool, there will be no difference in the result.

813 *What important property distinguishes heat from all other agents or substances in nature?*

The property of *passing through* and *existing in all kinds of matter* at *all times;* heat is *everywhere present*, and every body that exists contains it *without known limit.*

814 *Has ice heat?*

Yes, large quantities of it. Sir Humphrey Davy, by friction, extracted heat from two pieces of ice, and quickly melted them, in a room cooled below the freezing point, by rubbing them against each other.

815 *How do we measure the quantity of heat in different bodies, or judge of its effects?*

Only by the *change in bulk* or *appearance* which different bodies assume, according as heat is added or subtracted.

816 *According to what law does heat diffuse or spread itself?*

Heat diffuses or spreads itself among neighboring bodies *until all have acquired the same temperature;* that is to say, until all will similarly affect the thermometer.

817 *Why does a piece of iron thrust into burning coals become hot among them?*

Because the heat passes from the coals into the iron until the metal has acquired an equal temperature.

818 *What is cold?*

Cold is a relative term expressing only the *absence of heat in a degree;* not its total absence, for heat exists always in all bodies.

819 *When the hand touches a body having a higher temperature than itself, why do we call it hot?*

Because on account of the law that heat diffuses itself among neighboring bodies until all have acquired the same temperature, heat passes from the body of higher temperature to the hand, and causes a peculiar sensation, which we call *warmth.*

820 *Under what circumstances do we call a body cold?*

When we touch a body having a temperature *lower than that of the hand,* heat, in accordance with the above law, passes out from the hand to the body touched, and occasions the sensation which we call *cold.*

821 *What, then, really are the sensations of heat and cold?*

Merely *degrees of temperature,* contrasted by name in reference to the peculiar temperature of the individual speaking of them.

822 *When is a body said to be incandescent or ignited?*

When the body naturally *incapable* of emitting light is heated to sufficient extent to become *luminous.*

823 *What is flame?*

Flame is *ignited gas* issuing from a burning body.

824 *What is fire?*

The appearance of *heat and light in conjunction,* produced by the combustion of inflammable substances.

825 *What character was attributed to fire by the ancient philosophers?*

They used the term *fire* as a characteristic of the matter of heat, and regarded it as one of the *four elements of nature.*

826 *Enumerate the general physical properties of heat.*

It is *invisible, without weight,* with great tendency to *diffuse itself,* and is *absorbed* by all bodies.

827 *What are the principal effects of heat?*

Expansion, liquefaction, vaporization, and *ignition.*

828 *What do we understand by the term caloric?*

Caloric is a name often used to indicate the agent which produces the sensation of warmth; since the term "heat," as generally used, refers only to the sensation.

829 *Is caloric equally distributed over the globe?*

No; at the *equator* the *average temperature* is $82\frac{1}{2}°$

while at the *poles* it is believed to be about 13° below zero.

"*Average temperature*"—that is, the mean or medium temperature.

"ZERO"—the point from which a thermometer is graduated; it is 32° below freezing, Fahrenheit's thermometer.

830 *How many sources of heat are recognised to exist?*

Six.

831 *What are they?*

1. *The sun*; 2. *The interior of the earth*; 3. *Electricity*; 4. *Vital action*; 5. *Mechanical action*; 6. *Chemical action.*

CHAPTER II.

THE SUN A SOURCE OF HEAT.

832 *What is the great natural source of heat?*

The *sun.*

833 *Why do burning-glasses set fire to substances submitted to their power?*

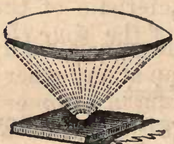


Fig. 35.

Because, when the rays of the sun pass *through* the burning-glass, they are bent towards *one point*, called the "focus;" in consequence of which the light and heat at *this point* are very greatly increased.

Fig. 35 represents the manner in which a burning-glass concentrates or bends down the rays of heat until they meet in a focus.

834 *Do the rays of the sun ever set fire to natural substances without the assistance of a burning-glass?*

No; the rays of the sun, even in the torrid zone, are never hot enough to kindle natural substances, unless *concentrated* by a *burning-glass.*

835 *Does the heat of the sun possess any different properties from artificial heat?*

The heat of the sun *passes* readily *through glass*, whereas this property is possessed by artificial heat in a *very small degree*.

836 *What is the generally received opinion at present, in regard to the actual temperature of the visible surface of the sun?*

That the *temperature* of its luminous coating is much *more elevated* than any *artificial heat* we are able to produce.

837 *Why is the heat of the sun always greater in some portions of the earth than at others?*

Owing to the *position* of the *earth's axis*, the rays of the sun always fall *more directly* upon the central portion of the earth than they do at the poles or extremities.

838 *Upon what does the succession of spring, summer, autumn, and winter, and the variations of temperature of the seasons, depend?*

Chiefly upon the *position* of the *sun* in relation to the earth.

839 *When do we experience the greatest amount of heat from the rays of the sun?*

When its rays fall *most perpendicularly.*

840 *Why is the heat of the sun greatest at noon?*

Because for the day the sun has reached the highest point in the heavens, and its rays fall *more perpendicularly* than at any other time.

841 *Why is it warmer in summer than in winter?*

Because in summer the position of the sun is such that its *rays fall more perpendicularly* than at any other season. The sun is longer above the horizon in summer than in winter, and consequently imparts the greatest amount of heat.

842 *Why is it colder in winter than in summer?*

Because in winter the position of the sun is such that its *rays fall more obliquely* upon the earth than at any other season. The sun is also for a less time above the horizon in winter than in summer, and consequently imparts less heat.

843 *Upon what does the heating power of the sun depend in a great measure?*

Upon its *altitude* or *height above the horizon;* the greater its altitude, the more perpendicularly will its rays fall upon the earth, and the greater their heating effect; the less the altitude, the more obliquely will its rays fall, and the less their heating effect.

844 *Why should the difference in the inclination of the sun's rays falling upon the earth occasion a difference in their heating effect?*

Because the more the rays are inclined, the larger the space over which they fall.

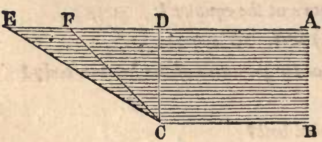


Fig. 36.

Let us suppose A B C D, *Fig.* 36, to represent a portion of the sun's rays; and C D a portion of the earth's surface upon which the rays fall perpendicularly, and C F and C E portions of the surface upon which they fall obliquely. Now, it is obvious that the surfaces C F and C E are greater than the surface C D; and as the same amount of rays of light and heat fall upon all the surfaces, it is clear that they will fall more densely upon the smaller surface (*i.e.* that it will be warmer there) and more diffusely over the inclined or oblique surface (where it will be colder).

845 *What is the greatest natural heat ever observed?*

On the west coast of Africa the thermometer (Fahrenheit) has been observed as high as 108° *in the shade;* Burckhardt, in *Egypt*, and Humboldt, in *South America*, observed it at 117° F.; and, in 1819, at Bagdad, the thermometer rose to 120° F. in the shade.

846 *What is the lowest atmospheric temperature ever observed?*

From 60° to 70° below the zero of Fahrenheit's thermometer. This temperature has been observed by Dr. Kane and other Arctic navigators.

847 *What is the greatest artificial cold ever produced?*

220° *below zero*, which temperature was attained by Prof. Natterer. At this temperature, pure alcohol and ether did not freeze.

848 *What is the estimated temperature of the space above the earth's atmosphere?*

58° *below zero.*

849 *At what temperature does mercury freeze?*

38°·6 below zero.

850 *At what temperature does fresh water freeze?*

At 32° *above zero.*

851 *At what temperature does salt or sea water freeze?*

At 28°·5 above zero.

852 *Why does it require a greater amount of cold to cause sea water to congeal, than it does fresh water?*

Because *sea water* contains *salt* and other substances which tend to prevent congelation.

853 *What is the average temperature at the equator?*

In *America*, 81°·5; in *Africa*, 83°.

854 *What is blood-heat, or the vital temperature of the human body?*

98°.

855 *At what temperature does alcohol boil?*

Under the ordinary atmospheric pressure at 173°·5.

856 *At what temperature does water boil?*

Under the ordinary atmospheric pressure at 212°.

857 *At what temperature does lead melt?*

At 594°.

858 *At what heat does mercury boil?*

At 661° under the common atmospheric pressure.

859 *At what temperature do brass, copper, silver, and gold melt?*

Brass at 1869°; *copper*, 1996°; *silver*, 1873°; *gold*, 2016°.

860 *At what temperature does cast-iron melt?*

At 2786°.

861 *What is the greatest degree of artificial heat which we have been enabled to measure?*

A furnace heat of 3280°: at this heat wrought iron and platinum did not melt.

CHAPTER III.

OTHER SOURCES OF HEAT BESIDES THE SUN.

862 *How far below the surface of the earth does the influence of solar heat extend?*

The depth varies from 50 *to* 100 *feet;* never, however, exceeding the latter distance.

863 *How do we know that the earth is a source of heat?*

Because we find as we descend into the earth and pass beyond the limit of solar heat, *that the temperature constantly increases.*

864 *At what rate does the temperature increase?*

About *one degree* of the thermometer for *every fifty feet.*

865 *Supposing the temperature to continue to increase according to this ratio, what would be its effects at different depths?*

At the depth of *two miles* water would be converted into steam; at *four miles*, tin would be melted; at *five miles*, lead; and at *thirty miles*, almost every earthy substance would be reduced to a fluid state.

866 *To what cause may earthquakes and volcanoes be attributed?*

Undoubtedly to the agency of the *internal heat of the earth.*

867 *What effect has the internal heat of the earth on the temperature of the surface?*

No sensible effect: it has been calculated that it affects the temperature of the surface less than $\frac{1}{30}$ of a degree of the thermometer.

868 *Why, if so great an amount of heat exist in the interior of the earth, does it not appear more manifest upon the surface?*

Because the materials of which the exterior strata or crust of the earth is composed, *do not conduct* it to the surface from the interior.

869 *In what manner is electricity a source of heat?*

When an electric current passes from one substance to another, the substance which serves to conduct it is very frequently heated; but in what manner the heat is produced, we have no positive information.

870 *How great a degree of heat is electricity capable of generating?*

The *greatest known heat* with which we are acquainted, is produced by the agency of the electric or galvanic current. All known substances can be melted or volatilized by it.

871 *Has the heat generated by electricity been employed for any practical or economical purposes?*

Not to any great extent; but for philosophical experiments and investigations it has been made quite useful.

872 *What is chemical action?*

We apply the term chemical action to those operations, whatever they may be, by which the *weight*, *form*, *solidity*, *color*, *taste*, *smell*, and *action* of substances become changed; so that *new bodies* with quite different properties are formed from the *old*.

873 *How does chemical action become a source of heat?*

Many bodies, when their original constitution is altered, either by the abstraction of some of their component parts, or by the addition of other substances not before in combination with them, *evolve heat* while the change is taking place.

874 *Explain by illustration what you mean.*

Water is cold, and sulphuric acid is cold; but if these two *cold* liquids be mixed together, they will produce *intense heat.*

875 *Why does cold water poured on lime make it intensely hot?*

Because heat is evolved by the *chemical action* which takes place when the cold water combines with the lime.

Heat is always *evolved* when a fluid is converted into a *solid* form. Heat is always *absorbed* when a solid is changed into a *liquid* state. As the water is changed from its liquid form when it is taken up by the lime, therefore heat is given off.

876 *Where does the heat come from?*

It was in the water and lime before, but was in a *latent state.*

877 *Was there heat in the cold water and lime before they were mixed together?*

Yes. *All* bodies contain heat.

878 *Is there heat even in ice?*

Yes; but it is *latent* (*i.e.* not perceptible to our senses).

Latent, from the Latin word *lateo* (to lie hid).

879 *Does cold iron contain heat?*

Yes; *everything* contains heat; but when a thing *feels cold*, its heat is *latent.*

880 *What is meant by latent heat?*

Heat *not perceptible to our feelings.* When anything contains heat without *feeling* the hotter for it, that heat is called "*latent heat.*"

881 *Does cold iron contain latent heat?*

Yes; and when a blacksmith *compresses the particles* of iron by his hammer, he brings *out* latent heat; and this makes the iron red hot.

882 *Why is the air in the spring, when the ice and snow are melting, always very chilly and cold?*

Solid bodies, in passing to the liquid state, *absorb heat* in large quantities; when ice and snow are thawing, they absorb heat from the air, in consequence of which its temperature is greatly reduced.

883 *Why does the weather always moderate on the fall of snow?*

Bodies, in passing from the liquid to the solid state, *give out heat;* snow is frozen water, and in its formation heat is imparted to the atmosphere, and its temperature increased.

884 *Why does the temperature of melting ice and snow never exceed 32°?*

Because all the heat imparted to melting ice and snow *becomes insensible*, until the liquefaction is complete.

885 *Can we be made to feel the heat of ice or snow?*

Yes. Into a pint of snow put half as much *salt;* then plunge your hands into the liquid; and it will feel so intensely cold that the snow itself will seem *warm* in comparison to it.

886 *Are salt and snow really colder than snow?*

Yes, many degrees; and by dipping your hand into the mixture *first*, and into snow *afterwards*, the snow will seem to be comparatively warm.

887 *Why do salt and snow mixed together produce intense cold?*

The salt and snow are both solids; when they are mixed, the salt causes the snow to melt by reason of its *attraction for water*, and the water formed dissolves the salt: so that both pass from the solid to the liquid condition, and a large quantity of heat is absorbed. As this heat is derived from that which previously existed in the solids themselves in a sensible state, its abstraction occasions a reduction of temperature.

888 *How is heat produced by mechanical action?*

1. By *percussion;* 2. By *friction;* and 3. By *condensation.*

889 *What is meant by percussion?*

The shock produced by the collision of two bodies; as when a blacksmith strikes a piece of iron on his anvil with his hammer.

890 *Why does striking iron make it red hot?*

Because it *condenses the particles* of the metal, and makes the latent heat *sensible.*

891 *What is meant by friction?*

The act of *rubbing two things together*, as the Indians rub two pieces of *wood* together to produce fire.

892 *How do savages produce fire by merely rubbing two pieces of dry wood together?*

They take a piece of dry wood, sharpened to a point, which they rub quickly up and down a *flat piece* till a *groove* is made; and the *dust* (collected in this groove) *catches fire.*

893 *Why does the dust of the wood catch fire by rubbing?*

Because *latent heat* is developed from the wood *by friction.*

894 *Do not carriage wheels sometimes catch fire?*

Yes; when the wheels are *dry*, or *fit too tightly*, or *revolve very rapidly.*

Fig. 37.

Fig. 37 represents an Indian explaining the method of kindling a fire by the friction of two pieces of wood.

895 *Why do wheels catch fire in such cases?*

Because the *friction* of the wheels against *the axle-tree* disturbs their *latent heat*, and produces ignition.

896 *What is the use of greasing cart wheels?*

Grease *lessens the friction;* and, because there is *less friction*, the latent heat of the wheels is less disturbed.

897 *Does a body ever cease to give out heat by friction?*

No; however long the operation may be continued.

898 *What conclusions respecting the nature of heat have philosophers drawn from this fact?*

That heat cannot be a *material substance*, but merely a *property of matter.*

899 *Why is it easier to produce heat from the friction of rough surfaces than smooth ones?*

Because in the friction of rough surfaces certain particles *are rubbed off*, which, *being small*, are *readily condensed*, and made to evolve their latent caloric.

900 *Why, when you rub a smooth metallic surface, as a button, for example, against a piece of plank, does the metal become more heated than the wood?*

Because the caloric is *forced out of the wood*, as it were, by the compression of its parts, and the button receives most of the caloric, owing to a stronger attraction for it, than is possessed by the wood.

901 *Why does a friction match, drawn over sand paper or other rough substance, ignite?*

When the match is drawn over sand paper, or other rough substance, certain phosphoric particles are rubbed off, and *being compressed* between the match and the paper, their heat is raised sufficiently high to ignite them, and fire the match. If the match be drawn over a *smooth* surface, the compression *must be increased*, for the temperature of the whole phosphoric mass must be raised in order to cause ignition.

902 *What singular property have most living animal bodies?*

The property of *maintaining* in themselves an *equable temperature*, whether surrounded by bodies that are hotter or colder than they are themselves.

903 *Illustrate this fact.*

The sailors of the Arctic exploring expedition during the polar winter, while breathing air that froze mercury, still had in them the natural warmth of 98° Fahrenheit above zero; and the inhabitants of India, where the same thermometer sometimes stands 115° in the shade, have their blood at no higher temperature.

904 *Do vegetables possess in any degree this property of maintaining a constant temperature within their structure?*

Growing or *fresh* vegetables have this property to a *certain extent.*

905 *What, then, is vital heat?*

The heat generated or excited by the *organs* of a *living structure.*

906 *What is the cause of vital or animal heat?*

The cause of animal heat is not certainly known or determined; it is supposed to be due to *chemical action*, the result of *respiration* and *nervous excitation.*

907 *Has the power of animals to preserve a peculiar temperature any limits?*

Yes; intense cold suddenly coming upon a man who has not sufficient protection, first causes a sensation of pain, and then brings on an almost irresistible sleepiness, which if indulged in proves fatal. A great excess of heat also cannot long be sustained by the human system.

908 *Does each species of animal appear to have a peculiar temperature?*

Yes; each species of animal and vegetable appears to have a temperature *natural* and *peculiar* to itself, and from this diversity different races are fitted for different portions of the earth's surface.

909 *What effect does the peculiarity of temperature have upon the distribution and location of animals and plants upon the earth's surface?*

The different species are confined and circumscribed within *certain districts*, depending mainly on their relations to heat. Thus, the orange-tree and the bird of Paradise are confined to warm latitudes; the pine-tree and the Arctic bear, to those which are colder.

910 *What curious fact in relation to a species of whale illustrates the influence of temperature in defining locations?*

It has been ascertained that at least one species of whale is precluded from migrating from the north to the south, from its inability to live in the heated waters of the equator.

911 *When animals or plants are removed from their peculiar and natural districts to one entirely different, what changes take place?*

They either *cease to exist*, or *change their character* in such a way as to adapt themselves to the climate.

912 *What curious illustrations do we find of this?*

The *wool* of the northern sheep changes in the tropics to a species of *hair*. The *dog* of the torrid zone is nearly destitute of hair. *Bees* transported from the north to the region of perpetual summer *cease to lay up stores of honey*, and lose in a great measure their habits of industry.

913 *How has nature provided for the protection of animals against the modifications of temperature?*

By covering their bodies with a *form of fur, or hair, or feathers*, in the exact degree required, and to such an extent as to vary the covering in the same animal according to the climate and season.

914 *What one species of organized beings is fitted to live in all climates?*

Man alone is capable of living in all climates, and of migrating freely to all portions of the earth.

CHAPTER IV.

HOW HEAT IS COMMUNICATED.

915 *In what three ways may heat be communicated?*

By *direct contact*, by *conduction* and *convection*, and by *radiation*.

916 *How may heat be communicated by contact?*

When a hot body touches a cold one, the *heat passes directly* from one into the other, as when it enters a bar of iron put into the fire, or the hand immersed in hot water.

917 *When is heat communicated by conduction?*

When the heat *travels from particle to particle* of the substance, as from the end of the iron bar placed in the fire to that part of the bar most remote from the fire.

918 *When is heat communicated by radiation?*

When the heat *leaps*, as it were, from a hot to a cold body *through an appreciable interval of space*, as when a body is warmed by placing it before a fire removed to a little distance from it.

919 *In what way does a heated body cool itself?*

First, by giving off heat from its surface, either by *contact or radiation*, or *both conjointly;* and, *secondly*, by the heat in its interior passing from particle to particle by conduction through its substance to the surface.

920 *In what manner does a cold body become heated?*

First, by heat passing into its surface either by *contact* or *radiation*, or by *both conjointly;* and, *secondly*, by the heat at its surface passing from particle to particle through its interior portions *by conduction.*

921 *Does heat pass through all bodies with the same velocity?*

No; some substances oppose very little impediment to its passage, while through others it is transmitted slowly.

922 *Into what two classes are bodies divided in respect to their conduction of heat?*

Into *conductors* and *non-conductors;* the former are such as allow heat to pass freely through them; the latter comprise those which do not give an easy passage to it.

923 *What are the best conductors of heat?*

Dense, solid bodies, such as metals, glass, some varieties of stone, etc.

924 *What are the worst conductors of heat?*

All *light* and *porous bodies;* such as hair, fur, wool, charcoal, and so on.

925 *Why do some things feel colder than others?*

Principally because they are *better conductors*, and draw off heat from our body much faster.

926 *Why does a piece of wood blazing at one end not feel hot at the other?*

Because *wood is so bad a conductor* that heat does not traverse freely through it; hence, though one end of a stick be blazing, the other end may be quite cold.

927 *Why does hot metal feel more intensely warm than hot wool?*

Because metal gives out a much *greater quantity of heat* in the *same space of time;* and the *influx* of heat is, consequently, *more perceptible.*

928 *Why does a poker, resting on a fender, feel colder than the hearth-rug, which is farther off from the fire?*

Because the poker is an *excellent conductor*, and draws heat from the hand much *more rapidly* than the woollen hearth rug, which is a very *bad conductor:*

though both, therefore, are *equally warm*, the *poker* seems to be the *colder*.

929 *Why does a stone or marble hearth feel to the feet colder than a carpet or hearth-rug?*

Because *stone* and *marble* are *good* conductors; but *woollen carpets* and *hearth-rugs* are very *bad* conductors.

930 *Why does the stone hearth make our feet cold?*

As soon as the hearthstone has absorbed a portion of heat from our feet, it instantly disposes of it, and calls for a *fresh supply;* till the hearthstone has become of the *same temperature as the foot placed upon it.*

931 *Do not also the woollen carpet and hearth-rug conduct heat from the human body?*

Yes; but being very *bad* conductors, they convey the heat away *so slowly* that the loss is scarcely perceptible.

932 *Is the cold hearthstone in reality of the same temperature as the warm carpet?*

Yes; everything in the room, except our bodies, is really of *one temperature;* but some things *feel* colder than others, because they are *better conductors.*

933 *How long will the hearthstone feel cold to the feet resting on it?*

Till the *feet* and the *hearthstone* are *both of the same temperature;* and then the sensation of cold in the hearthstone will go off.

934 *Why would not the hearthstone feel cold, when it is of the same temperature as our feet?*

Because the heat would no longer *rush out of our feet into the hearthstone*, in order to produce equilibrium.

935 *Why are cooking vessels often furnished with wooden handles?*

Because wood *is not a good conductor* like metal; and therefore *wooden handles* prevent the heat of the vessel from rushing into our hands to burn them.

936 *Why do persons use paper or woollen kettle-holders?*

Because paper and woollen are both very *bad conductors of heat*, in consequence of which the heat of the kettle does not *readily pass through them* to the hand.

937 *Does the heat of the boiling kettle never get through the woollen or paper kettle-holder?*

Yes; but though the kettle-holder became as hot as the kettle itself, it would never *feel* so hot.

938 *Why would not the kettle-holder feel so hot as the kettle, when both are of the same temperature.*

Because it is a very *bad* conductor, and *disposes of its heat too slowly to be perceptible;* but metal (being an *excellent* conductor) disposes of its heat *so quickly*, that the sudden influx is painful.

939 *When we plunge our hands into a basin of water, why does it produce a sensation of cold?*

Because water is a *better conductor* than air; and, as it draws off the heat from our hands *more rapidly*, it *feels colder*.

940 *Why does the conducting power of water make it feel colder than air?*

Because it *abstracts heat from our hands so rapidly* that we *feel* its loss; but the air abstracts heat *so very slowly* that its *gradual loss is hardly perceptible.*

941 *Is water a good conductor of heat?*

No; *no* liquid is a *good* conductor of heat; but yet water is a *much better conductor* than *air*.

942 *Why is water a better conductor of heat than air?*

Because *it is more dense;* and the conducting power of any substance depends upon its *solidity*, or the *closeness of its particles.*

943 *How do you know that water is not a good conductor of heat?*

Because it may be made to *boil at its surface*, without imparting sufficient heat to *melt ice a short distance below the surface.*

944 *Why are not liquors good conductors of heat?*

Because the heat (which should be transmitted) *produces evaporation*, and *flies off in the vapor*.

945 *If air is not a good conductor, how can we make use of it in warming our houses by means of stoves and furnaces?*

In the case of a stove or furnace, the air which is in contact with the fire or the heated surface, first becomes heated, expands, and rises; cold air rushes in to supply its place, is heated, and ascends in like manner, and this interchange goes on until all the air in the room is heated.

946 *If air be a bad conductor of heat, why should we not feel as warm without clothing as when we are wrapped in wool and fur?*

Because the air (which is cooler than our body) *is never at rest;* and every fresh particle of air *draws off a fresh portion of heat.*

947 *How does the ceaseless change of air tend to decrease the warmth of that part of the body devoid of clothing?*

Thus: the air (which cases the body) absorbs as much heat as it can while it remains in contact; being then blown away, it makes room for a *fresh coat of air*, which absorbs *more* heat.

948 *Does the air which encases a body devoid of clothing become (by contact) as warm as the body itself?*

It would do so if it remained *motionless;* but as it remains only a *very short time*, it absorbs as much heat as it can in the time, and passes on.

949 *Why do we feel colder in windy weather than in a calm day?*

Because the particles of air *pass over us more rapidly*, and every *fresh* particle takes from us *some* portion of heat.

950 *Why are woollens and furs used for clothing in cold weather?*

Because they are *very bad conductors* of heat; and therefore *prevent the warmth of the body from being drawn off* by the cold air.

951 *Do not woollens and furs actually impart heat to the body?*

No; they merely *prevent the heat of the body from escaping.*

952 *Where would the heat escape to, if the body were not wrapped in wool or fur?*

The heat of the body would *fly off* into the air; for the cold air (coming in contact with our body) would *gradually draw away its heat*, till it was as cold as the air itself.

953 *What, then, is the principal use of clothing in winter-time?*

1. To prevent the animal heat from escaping too freely; and

2. To protect the body from the *external air* (or wind), which would carry away its heat too rapidly.

954 *Why are wool, fur, hair, and feathers such slow conductors of heat?*

Because a *great quantity of air* lurks entangled between the fibres; and *air* is a *very bad* conductor of heat.

The warmest clothing is that which fits the body rather *loosely*, because more hot air will be confined by a moderately *loose* garment than by one which fits the body *tightly*.

955 *How are whales, seals, and other warm-blooded animals that live in the water protected against the cold?*

They are enveloped, *beneath the skin*, with a thick coating of "*blubber*" or *fat*, which, like fur, hair, and feathers, is a non-conductor of heat, and serves to protect them in like manner.

956 *Why are blankets and warm woollen goods always made with a nap or projection of fibres on the outside?*

Because the *nap* or *fibres retain air* among them, which, from its non-conducting properties, serves to increase the warmth of the material.

957 *How does the covering of hair, wool, and feathers serve to keep animals cool in hot weather, as well as warm in cool weather?*

In warm weather the *non-conducting medium* will not allow the heat to *enter* the body *from without*; in cold weather the heat of the body *cannot escape from within*.

958 *Why do we wrap up ice in flannel to keep it from melting?*

Because the flannel, being a *non-conductor*, does not allow the heat of the atmosphere *to penetrate* to the ice.

959 *In the construction of icehouses, why do we line the walls and roof with straw or sawdust?*

Because these substances are bad conductors of heat.

960 *Why is it good economy to furnish our houses in winter with double windows?*

The air confined between the two surfaces of glass is a non-conductor of heat, and equally opposes the escape of caloric from within, or the penetration of cold air from without.

961 *Why does a linen garment feel colder than a cotton one?*

Because *linen* is a *much better conductor* than cotton; and therefore (as soon as it touches the body) it draws away the heat *more rapidly*, and produces a greater sensation of cold.

962 *Why is the face cooled by wiping the temples with a fine cambric handkerchief?*

Because the fine fibres of the cambric have a *strong capillary attraction for moisture*, and are *excellent conductors* of heat; in consequence of which the moisture and heat are *abstracted from the face* by the cambric, and a sensation of coolness produced.

963 *Why would not a cotton handkerchief do as well?*

Because the coarse fibres of cotton have less capillary attraction, and are *very bad conductors;* in consequence of which the heat of the face would be *increased* (rather than *diminished*) by the use of a *cotton* handkerchief.

964 *Is the soil a good conductor of heat?*

No; it is a very *bad* conductor of heat.

965 *Why is the soil a bad conductor of heat?*

Because its particles are not *continuous;* and the power of *conducting* heat depends upon the *density of matter.*

966 *Why is the soil (below the surface) warmer in winter than the surface itself?*

Because it is a *bad* conductor of heat; and therefore (although the ground be frozen) the frost rarely penetrates more than a *few inches below the surface.*

967 *Why is the soil (below the surface) cooler in summer than the surface itself?*

Because it is a *bad* conductor of heat; and therefore (although the *surface be scorched* with the burning sun) the intense heat cannot penetrate to the *roots* of the plants and trees.

968 *Show the wisdom of the Creator in making the soil a bad conductor.*

If the *heat and cold could penetrate the soil deeply* (as freely as the heat of a fire penetrates iron), the springs would be dried up in summer and frozen in winter; and all vegetation would perish.

969 *Why is water from a spring always cool, even in summer?*

Because the soil is *so bad a conductor*, that the burning rays of the sun can penetrate only a few inches below the surface; in consequence of which the *springs of water are not affected* by the heat of summer.

970 *How does the non-conducting power of snow protect vegetables from the frost and cold?*

It prevents the *heat* of the soil from being *drawn off* by the cold air which rests upon it.

971 *Why is snow a non-conductor of heat?*

Principally because it contains a large quantity of *air* between its particles.

972 *Why is it cool under a shady tree in a hot summer's day?*

1. Because the overhanging foliage *screens off the rays of the sun;*

2. As the rays of the sun are warded off, the *air* (beneath the tree) is not heated by the *reflection of the soil;* and

3. The leaves of the trees, being *non-conductors*, also obstruct the transmission of heat.

973 *Why does a metal spoon (left in a kettle) retard the process of boiling?*

Because the metal spoon (being an excellent *conductor*) *carries off the heat from the water*, and (as heat is carried off by the spoon) the water takes a longer time to boil.

974 *Why does paint preserve wood?*

1. Because it covers the surface of the wood, and prevents both air and damp from penetrating into the pores;

2. Because paint (especially white paint), being a *bad conductor*, preserves the wood of a more uniform temperature; and

3. Because it fills up the pores of the wood, and prevents insects and vermin from harboring therein and eating up the fibre.

975 *Why are furnaces and stoves (where much heat is required) built of porous bricks?*

Because bricks are *bad conductors*, and *prevent the escape of heat;* in consequence of which they are employed where great heat is required.

976 *Why do cellars feel warm in winter?*

Because the *external air* has not free access into them; in consequence of which they remain almost at an *even temperature*, which (in winter-time) is about 10 degrees *warmer* than the external air.

977 *Why do cellars feel cold in summer?*

Because the external air has not free access into them; in consequence of which they remain almost at an *even temperature*, which (in summer-time) is about 10 degrees *colder* than the external air.

978 *Why do the Laplanders wear skins with the fur inwards?*

Because the *dry skin* prevents the *wind* from penetrating to their body; and the *air* (between the hairs of the fur) soon becomes *heated by the body;* in consequence of which the Laplander in his fur is clad in *a case of hot air*, impervious to the *cold* and *wind.*

979 *In what respect is bark especially adapted as a covering for trees and shrubs?*

Bark is composed of matter which is *very slowly permeable by heat*, and, like hair and fur in animals, is especially adapted for securing the temperature necessary to vegetable life.

980 *What is the temperature of the sap of healthy trees during the summer?*

It is *several degrees below* that of the surrounding atmosphere.

981 *What is the temperature of the sap of a healthy tree in the winter?*

Several degrees above that of the surrounding atmosphere.

982 *What occasions this difference between the temperature of the sap of a tree and the temperature of the surrounding atmosphere?*

The *vital action* of the tree.

It is also a noticeable fact that sap drawn from a tree will freeze at the same temperature as water, while the sap circulating in the tree, under the influence of vital agency, will not freeze until reduced *seventeen degrees below* the freezing-point of water.

983 *Why in a frozen pond or lake is the ice always thinner, and often entirely wanting, in those parts where springs exist upon the bottom?*

Because the spring water, coming from a point in the earth *below* the influence of the frosts, is *elevated* in temperature, and by *imparting its heat* prevents an accumulation of ice upon the surface above.

984 *Is there in reality any positive warmth in the materials of clothing?*

No; but we consider clothing warm or cool according as it *impedes* or *facilitates* the passage of heat to or from the surface of our bodies. The thick cloak which guards a Spaniard against the cold of winter is also in summer used by him as a protection against the direct rays of the sun; and, while in temperate climates flannel is the warmest article of dress, we cannot at the same time preserve ice more effectually than by inclosing it in its softest folds.

985 *Does fine or coarse woollen cloth make the warmest clothing?*

The *finer* the cloth, the more slowly it conducts heat. Fine cloths, therefore, are warmer than coarse ones.

986 *Is silk a good conductor of heat?*

No; it is a *bad conductor* of heat. Spun silk allows the heat of the body to pass off more quickly than wool; but raw silk confines it more than wool.

987 *The sheets of a bed feel cold and the blankets warm: is there any difference in the respective temperature of these articles?*

No; the temperature of both the sheets and the blankets is *always exactly the same.*

988 *Why, then, does one feel colder than the other?*

Sheets feel colder than the blankets because they are *better conductors of heat*, and carry off the heat more rapidly from the body; but when by the continuance of the body between them they acquire the same temperature, they will then feel even *warmer* than the blankets.

989 *In the summer a still, calm atmosphere feels warm, but if a wind arises, the same atmosphere feels cold: has there been any real change of temperature?*

No; for a thermometer suspended *under shelter* and in a *calm place* will indicate the *same temperature* as a thermometer on which the wind blows.

990 *Why do we then consider that the air has grown colder?*

Because the air in motion by the wind *conducts off* the heat from our bodies *faster* than the same air at rest.

991 *What is meant by the convection of heat?*

Heat communicated by being *carried* to another thing or place; as the hot water resting on the *bottom* of a kettle carries heat to the water through which it ascends.

992 *Are liquids good conductors of heat?*

No; liquids are bad *conductors;* and are therefore made hot by *convection*.

993 *Why are liquids bad conductors of heat?*

This peculiarity is referable to the *mobility* which subsists among the particles of *all fluids*, and to the change in the size of the particles, which is invariably produced by their change in temperature.

The constituent particles of solid bodies being incapable of changing their matérial position and arrangement, the heat can only pass through them, from particle to particle, by a slow process; but when the particles forming any stratum of liquid are heated, their mass, expanding, becomes lighter, bulk for bulk, than the colder stratum immediately above it, and ascends, allowing the superior strata to descend.

994 *Explain how water is made hot.*

When the heat enters at the bottom of a vessel containing water, a *double set of currents* is immediately established,—one of *hot* particles *rising* towards the

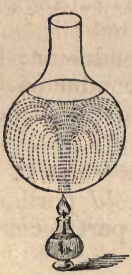


Fig. 38.

surface, and the other of *colder* particles *descending* to the *bottom*. The portion of liquid which receives heat from below is thus continually mixed through the other parts, and the heat is diffused by the motion of the particles among each other.

These currents take place so rapidly, that if a thermometer be placed at the bottom and another at the top of a long jar, the fire being applied below, the upper one will begin to rise almost as soon as the lower one. The movement of the particles of water in boiling will be understood by reference to *Fig.* 38.

995 *What common experiment proves that water is a bad conductor of heat?*

When a blacksmith immerses his red-hot iron in a tank of water, the water which surrounds the iron is made *boiling hot*, while the water *not immediately in contact* with it remains quite *cold*.

Fig. 39.

If a tube nearly filled with water is held over a spirit lamp, as in *Fig.* 39, in such a manner as to direct the flame against the upper layers of the water, the water will be observed to boil at the top, but remain cool below. If quicksilver, on the contrary, be so treated, its lower layers will speedily become heated. The particles of mercury will communicate the heat to each other, but the particles of water will not do so.

996 *Why is water in such continual ferment when it is boiling?*

This commotion is mainly produced by the *ascending* and *descending currents* of hot and cold water.

The escape of *steam* from the water contributes also to increase this agitation.

997 *How do these two currents pass each other?*

The *hot ascending current* rises up through the *centre* of the mass of water; while the *cold descending currents* pass down by the metal *sides of the kettle*.

998 *Why is heat applied to the bottom, and not to the top of the kettle?*

Because the heated water always *ascends* to the *surface*, heating the water through which it passes; if, therefore, heat were applied to the *top* of a vessel, the water *below the surface* would be heated very slowly.

999 *As the lower part of a grate is made red hot by the fire above, why would not the water boil if fire were applied to the top of a kettle?*

The *iron* of a grate is an excellent conductor; if, therefore, *one* part be heated, the heat is conducted to *every* other part; but *water* is a very *bad conductor*, and will not diffuse heat in a similar way.

1000 *If you wish to cool liquids, where should the cold be applied?*

To the *top* of the *liquid;* because the *cold* portions will always *descend*, and allow the warmer part to come in contact with the cooling substance.

1001 *Does boiling water get hotter by being kept on the fire?*

No; not if the steam be suffered to escape.

1002 *Why does not boiling water get hotter if the steam be suffered to escape?*

Because the *water* is converted into *steam* as fast as it boils; and the steam *carries away* the additional heat.

1003 *What is ebullition?*

When a liquid substance is heated sufficiently to form steam, the production of vapor takes place principally at that part where the heat enters; and when the heating takes place not from above, but from the bottom and sides, the steam as it is produced rises in bubbles through the liquid, and produces the phenomenon of boiling or ebullition.

1004 *What do we mean by the boiling point of a liquid?*

The *temperature* at which vapor rises with sufficient freedom to cause the phenomenon of *ebullition* is called the boiling point.

1005 *Do all liquids boil at the same temperature?*

No; the boiling point occurs in different liquids at very different temperatures.

1006 *Why does milk boil over more readily than water?*

Because the bubbles of milk, produced by the process of boiling, are more *tenacious* than the bubbles of water; and these bubbles, accumulating and climbing one above another, soon overtop the rim of the saucepan and run over.

1007 *Why does water simmer before it boils?*

Because the particles of water *near the bottom* of the kettle (being formed into *steam* sooner than the rest) *shoot upwards*, but are *condensed* again (as they rise) *by the colder water*, and produce what is called "simmering."

1008 *What is meant by simmering?*

A gentle tremor or *undulation* on the surface of the water. When water *simmers*, the bubbles *collapse beneath the surface*, and the steam is condensed to *water again;* but when water *boils*, the bubbles *rise to the surface*, and the *steam is thrown off*.

1009 *Why does boiling water swell?*

Because it is *expanded by the heat;* that is, the heat of the fire drives the particles of water *farther apart* from each other, and (as they are not *packed so closely together*) they take up *more room;* in other words, the water *swells.*

1010 *Why does boiling water bubble?*

Because the *vapor* (rising through the water) is *diffused*, and forces up bubbles in its effort to escape.

All the air of water is expelled at the commencement of its boiling.

1011 *Why does a kettle sometimes boil over?*

Because the water is *expanded by heat;* if, therefore, a kettle is *filled with cold water*, some of it must *run over* as soon as it is *expanded by heat.*

1012 *But I have seen a kettle boil over, although it has not been filled full of water: how do you account for that?*

If a fire be *very fierce*, the air and vapor are expelled so *rapidly*, that the *bubbles are very numerous*, and (towering one above another) reach the *top of the kettle*, and *fall over.*

1013 *Why is a pot (which was full to overflowing while the water was boiling hot) not full after it has been taken off the fire for a short time?*

Because (while the water is *boiling*) it is *expanded* by the heat, and fills the pot even to overflowing; but when it becomes cool, it *contracts* again, and occupies a much less space.

1014 *When steam pours out from the spout of a kettle, the stream begins apparently half an inch off the spout: why does it not begin close to the spout?*

Steam is really *invisible;* and the half inch (between the spout and the "*stream of mist*") is the *real steam*, before it has been condensed by air.

1015 *Why is not all the steam invisible as well as that half inch?*

Because the invisible particles are *condensed by the cold air*, and, rolling one into another, look like a thick mist.

1016 *What becomes of the steam, for it soon vanishes?*

After it has been condensed into mist, it is *dissolved by the air*, and dispersed abroad as *invisible vapor.*

1017 *And what becomes of the invisible vapor?*

Being *lighter* than air, it *ascends* to the upper regions of the atmosphere, where (being again *condensed*) it contributes to form *clouds.*

1018 *Why do sugar, salt, &c., retard the progress of boiling?*

Because they increase the *density* of water; and whatever increases the *density* of a fluid retards its boiling.

1019 *Why can liquids impart no additional heat after they boil?*

Because all *additional* heat is spent *in making steam.* Hence water will not boil a vessel of *water* immersed in it, because it cannot impart to it 212° of heat; but *brine* will, because it can impart *more* than 212° of heat before it is *itself* converted into steam.

Ether . . boils at	100	degrees	Syrup . . boils at	221	degrees.
Alcohol . . "	173½	"	Oil of turpentine	314	"
Water . . . "	212	"	Sulphuric acid	472	"
Water, with one-fifth salt, boils at	219	"	Linseed oil "	640	"
			Mercury . . "	656	"

Any liquid which boils at a *lower* degree, can be made to boil if immersed in a liquid which boils at a *higher* degree. Thus a cup of ether can be made to boil in a vessel of water; a cup of water, in a vessel of brine or syrup; but a cup of water will not boil if immersed in ether, nor a cup of syrup in water.

1020 *Is the boiling point of the same liquid always constant?*

Yes, under the *same conditions;* but it is liable to be affected by various circumstances.

1021 *What cause has a powerful influence in regulating the boiling point of liquids?*

The *pressure of the atmosphere:* if the pressure be less than usual, then the boiling point of water and all other liquids will be lower than usual; if the pressure increases, and the barometer rises, the temperature of ebullition will be proportionably increased.

1022 *If the atmospheric pressure be entirely removed, or if water be made to boil in a vacuum, at what temperature will ebullition commence?*

At a point 140° *lower* than in the open air.

1023 *To what temperature can water exposed to the air be heated under ordinary circumstances?*

To about 212° Fahrenheit; at this temperature water passes into steam or vapor.

1024 *Can water be heated beyond* 212°?

Yes; if subjected to *sufficient pressure*, it can be heated to *any extent* without boiling. There is no limit to the degree to which water may be heated, provided the vessel is strong enough to confine the vapor; but the expansive force of steam is so enormous under these circumstances, as to overcome the greatest resistance which has ever been exerted upon it.

1025 *Why does soup keep hot longer than boiling water?*

Because the *grease* and other ingredients floating in the soup *retain the heat* longer than the particles of water, and, at the same time, by their viscidity or tenacity, prevent the circulation of the heated particles.

1026 *How is air heated?*

By "*convective currents.*"

1027 *Explain what is meant by "convective currents."*

When a portion of air is heated, it *rises upwards in a current*, carrying the heat with it; other *colder air succeeds*, and (being *heated* in a similar way) *ascends also:* these are called "convective currents."

"*Convective currents,*" so called from the Latin words *cum vectus* (carried with), because the *heat* is "carried with" the current.

1028 *Is air heated by the rays of the sun?*

No; air is *not heated* (to any very great extent) *by the action of the sun's rays* passing through it.

1029 *Why, then, is the air hotter on a sunny day than on a cloudy one?*

Because the sun *heats the surface of the earth*, and the air (resting on the earth) is *heated by contact;* as soon as it is heated *it ascends*, while its place is supplied by *colder* portions, which are heated in turn also.

1030 *If air be a bad conductor, why does hot iron become cold by exposure to the air?*

Because it is made cold—1. By "convection;" and 2. By "radiation."

1031 *How is hot iron made cold by convection?*

The air resting on the hot iron (being intensely heated) rapidly ascends with the heat it has absorbed; *colder* air succeeding, *absorbs more heat* and ascends also; and this process is repeated till the hot iron *is cooled completely down.*

1032 *How is broth cooled by being left exposed to the air?*

It throws off *some* heat by *radiation;* but it is *mainly* cooled down by *convection.*

1033 *How is hot broth cooled down by convection?*

The air *resting* on the *hot broth* (being heated) *ascends;*[*] colder air succeeding *absorbs more heat*, and *ascends also;* and this process is repeated till the broth is *made cool.*

[*] The particles on the surface of the broth *sink* as they are cooled down, and *warmer* particles rise to the surface, which gradually assist the cooling process.

1034 *Why are hot tea and broth cooled faster by being stirred about?*

1. Because the agitation assists in bringing its *hottest particles* to the *surface;*

2. As the hotter particles are more rapidly brought into contact with the air, therefore *convection is more rapid.*

1035 *How does blowing hot food make it cool?*

It causes the air (which has been heated by the food) to *change more rapidly*, and give place to fresh *cold air.*

1036 *If a shutter be closed in the daytime, the stream of light (piercing through the crevice) seems in constant agitation: why is this?*

Because little *motes* and *particles of dust* (thrown into agitation by the violence of the *convective currents*) are made *visible* by the strong beam of light thrown into the room through the crevice of the shutter.

1037 *Why does milk boil more quickly than water?*

Milk is a *thicker* liquid than water, and consequently *less steam* escapes through the thick liquid (milk) than through the thin liquid (water); therefore the heat of the whole mass of the milk rises more quickly.

1038 *Why are fires placed near the floor of a room, and not towards the ceiling?*

Because heated air always *ascends.* If, therefore, the fire were not *near the floor,* the air of the *lower* part of the room would be elevated in temperature very slowly.

1039 *Would not the air of the lower part of a room be heated equally well if the fires were fixed higher up?*

No; the heat of a fire has a very little effect upon the air *below the level of the fire;* and therefore every fire should be as *near to the floor* possible.

1040 *Our feet are very frequently cold when we sit close by a good fire: explain the reason of this?*

As the air over the fire becomes heated and rises, *cold air* rushes through the crevices of the doors and windows, and *along the bottom of the room,* to supply the deficiency; and these currents of cold air *rushing constantly over our feet,* deprive them of their warmth.

1041 *What is meant by radiation of heat?*

The *emission* of rays of heat in *all directions.*

When the hand is placed near a hot body suspended in the air, a sensation of warmth is perceived, even for a considerable distance. If the hand be held beneath the body, the sensation will be as great as upon the sides, although the heat has to shoot down through an opposing current of air approaching it. This effect does not arise from the heat being conveyed by means of a hot current, since all the heated particles have a uniform tendency to rise; neither can it depend upon the conducting power of the air, because aerial substances possess that power in a very low degree, while the sensation in the present case is excited almost on the instant. This method of distributing heat, to distinguish it from heat passing by contact or conduction, is called *radiation.*

1042 *How do we designate heat so distributed?*

As *radiant* or *radiated* heat.

1043 *When is heat radiated from one body to another?*

When the two bodies are *separated* by a *non-conducting medium.*

1044 *On what does radiation depend?*

On the *roughness* of the radiating surface: thus, if metal be *scratched*, its radiating power is increased, because the *heat has more points to escape from.*

1045 *Does a fire radiate heat?*

Yes; and because *burning fuel emits rays of heat*, we *feel warm* when we stand before a fire.

1046 *Why does our face feel uncomfortably hot when we approach a fire?*

Because the fire radiates heat upon the face, which (not being covered) feels the effect immediately.

1047 *Why does the fire heat the face more than it does the rest of the body?*

Because the *rest* of the body is *covered* with clothing; which (being a *bad* conductor of heat) prevents the same sudden and rapid transmission of heat to the skin.

1048 *Do those substances which radiate heat absorb heat also?*

Yes. Those substances which *radiate most* also *absorb most heat;* and those which *radiate least* also *absorb the least* heat.

1049 *Does any thing else radiate heat besides the sun and fire?*

Yes; *all* things radiate heat in *some* measure, but *not equally well.*

1050 *What things radiate heat the next best to the sun and fire?*

All *dull* and *dark* substances are *good radiators* of heat; but all *light* and *polished* substances are *bad radiators.*

1051 *What is meant by being a "bad radiator of heat?"*

To radiate heat is to *throw off heat by rays*, as the sun; a polished tin pan does *not throw off the heat of boiling water* from its surface, but *keeps it in.*

1052 *Why does snow (at the foot of a tree or wall) melt sooner than in an open field?*

Because the tree or wall *radiates heat into the snow beneath*, which melts it.

1053 *Why should the flues (connected with stoves, etc.) be always blackened with black lead?*

In order that the heat of the flue may be more readily *diffused* throughout the room. Black lead radiates heat more freely than any other known substance.

1054 *Would a metal pot serve to keep water hot if it were dull and dirty?*

No; it is the bright *polish* of the metal which makes it a bad radiator; it it were *dull*, *scratched*, or *dirty*, the heat would *escape* very rapidly.

Water in hot weather is also kept *cooler* in bright metal than in *dull* or earthen vessels.

1055 *Why are dinner-covers made of bright tin or silver?*

Because light-colored and highly-polished metal is a *very bad radiator of heat;* and therefore bright tin or silver will not allow the heat of the cooked food to *escape through the cover by radiation.*

CHAPTER V.

THE PHENOMENA OF DEW.

1056 *What is Dew?*

Dew is the *moisture of the air condensed* by coming in contact with bodies colder than itself.

1057 *Why is the ground sometimes covered with dew?*

Because the surface of the earth (at sunset) is made so very *cold* by radiation, that the warm vapor of the air is *chilled* by contact, and condensed into dew.

1058 *Why is the earth made colder than the air after the sun has set?*

Because the *earth radiates* heat very freely, but the air does not; in consequence of which the earth is often five or ten degrees colder than the air (after sunset), although it may have been *warmer* than the air during the whole day.

1059 *Why is the surface of the earth generally warmer than the air during the day?*

Because the earth *absorbs* solar heat very freely, but the air does not; in consequence of which it is often many degrees warmer than the air during the day.

1060 *Why is the surface of the ground colder in a fine night than in a cloudy one?*

Because on a fine, clear, starlight night, *heat radiates from the earth freely*, and is lost in open space; but on a *dull* night, the clouds *arrest the process of radiation.*

1061 *Why is dew deposited most readily on a fine, clear night?*

Because the *surface of the ground radiates heat most freely* on a fine night, and (being cooled down by this loss of heat) *chills the vapor of the air into dew.*

1062 *Why is there no dew on a dull, cloudy night?*

Because the clouds *arrest the radiation of heat from the earth*, and (as the heat cannot freely escape) the surface is not sufficiently cooled down *to chill the vapor of the air into dew.*

1063 *Why is a cloudy night warmer than a fine, clear night?*

Because the clouds *prevent the radiation of heat from the earth;* in consequence of which the surface of the earth remains *warmer.*

1064 *How do clouds arrest or prevent the radiation of heat from the earth?*

The lower surfaces of the clouds *turn back* the rays of heat as they radiate or pass off from the earth, and prevent their dispersion into space.

1065 *What is the difference between dew and rain?*

In *dew*, the condensation is made near the *earth's surface.* In *rain*, the drops fall from a considerable height.

1066 *What is the cause of both dew and rain?*

Cold *condensing* the vapor of the *air* when near the point of *saturation.*

1067 *Why do mist and fog vanish at sunrise?*

Because the condensed particles are again *changed* into *invisible* vapor by the heat of the sun.

1068 *Why is dew most abundant in situations most exposed?*

Because the radiation of heat *is not arrested* by houses, trees, hedges, or any other thing.

1069 *Why is there scarcely any dew under a leafy tree?*

1. Because the thick foliage of a tree *arrests the radiation of heat* from the *earth;* and

2. A leafy tree radiates some of its own heat *towards the earth;* in consequence of which the ground underneath a tree is not sufficiently cooled down to chill the vapor of the air into dew.

1070 *Why is there never much dew at the foot of walls and hedges?*

1. Because they act as screens to *arrest* the radiation of heat from the *earth;* and

2. They themselves *radiate* some portion of *heat* towards the earth; in consequence of which the ground at the foot of walls and hedges is not sufficiently *cooled down* to chill the vapor of the air into dew.

1071 *Why is there no dew on a windy night?*

1. Because the wind *evaporates the moisture* as fast as it is deposited; and

2. It *disturbs* the radiation of *heat*, and thus diminishes the deposition of dew.

1072 *Why are valleys and hollows often thickly covered with dew, although they are sheltered?*

Because the surrounding hills prevent the *agitation* of the air, but do not overhang and screen the valleys sufficiently to *arrest* the radiation from their surfaces.

1073 *Why does dew fall more abundantly on some substances than on others?*

Because some substances radiate heat *more freely* than others, and therefore become *much cooler* in the night.

1074 *Why are substances which radiate the heat most freely always the most thickly covered with dew?*

Because they are the coldest substances, and therefore condense vapor most readily.

1075 *What kind of materials radiate heat most freely?*

Grass, wood, and the leaves of plants radiate heat very *freely;* but polished metal, smooth stones, and woollen cloth part with their heat very *tardily.*

1076 *Do the leaves of all plants radiate heat equally well?*

No. Rough, *woolly leaves* (like those of a hollyhock) radiate heat much *more freely* than *hard, smooth polished leaves,* like those of the common laurel.

1077 *Show the wisdom of the Creator in making grass, the leaves of trees, and all vegetables, excellent radiators of heat?*

As vegetables *require much moisture,* and would often *perish* without a plentiful deposit of dew, the Creator wisely made them to *radiate heat freely,* so as to *chill the vapor* (which touches them) *into dew.*

1078 *Will polished metal, smooth stones, and woollen cloth readily collect dew?*

No. While grass and leaves of plants *are completely drenched with dew,* a piece of *polished metal* or of *woollen cloth* (lying on the same spot) will be *almost dry.*

1079 *Why would polished metal and woollen cloth be dry, while grass and leaves are drenched with dew?*

Because the polished metal and woollen cloth *part with their heat so slowly,* that the vapor of the air is *not chilled into dew* as it passes over them.

1080 *Why is a gravel walk almost dry when a grass-plat is covered thick with dew?*

Because *grass* is a *good radiator,* and throws off its heat very *freely;* but *gravel* is a *very bad radiator,* and parts with its heat very slowly.

1081 *Is that the reason why grass is saturated with dew, and the gravel is not?*

Yes. When the vapor of warm air comes in contact with the *cold grass,* it is instantly chilled into dew; but it is *not so freely condensed* as it passes over gravel, because gravel is not so *cold* as the grass.

1082 *Why does dew rarely fall upon hard rocks and barren lands?*

Because rocks and barren lands are so *compact* and *hard*, that they can neither *absorb, nor radiate much heat;* and (as their *temperature varies but very little*) very little *dew* deposits upon them.

1083 *Why does dew fall more abundantly on cultivated soils than on barren lands?*

Because cultivated soils (being *loose* and *porous*) very freely *radiate* by night the heat which they absorb by day; in consequence of which they are *much cooled* down, and plentifully *condense* the vapor of the passing air *into dew.*

1084 *Show the wisdom of the Creator in this arrangement?*

Every plant and inch of land which *needs* the moisture of dew is adapted to *collect* it; but *not a single drop* is *wasted* where its refreshing moisture is *not required.*

1085 *When is dew most copiously distilled?*

After a hot day in summer or autumn, especially if the *wind* blows over a body of water.

1086 *Why is dew distilled most copiously after a hot day?*

Because the surface of the hot earth *radiates* heat very freely at sunset, and (being made much *colder* than the *air*) *chills* the *passing vapor* and condenses it into dew.

1087 *Why is there less dew when the wind blows across the land, than when it blows over a body of water?*

Because the winds which blow across the *land* are *dry* and *arid;* but those which cross the *water* are *moist* and full of *vapor.*

1088 *How does the dryness of the wind prevent dew-falls?*

As winds (currents of air) which blow over the land are very dry, they imbibe the moisture of the air; in consequence of which there is *very little* left to be condensed into *dew.*

1089 *Why is meat very subject to taint on a moonlight night?*

Because it *radiates heat very freely* in a bright moonlight night; in consequence of which it is soon covered with *dew*, which produces rapid *decomposition*.

1090 *How do moonlight nights conduce to the rapid growth of plants?*

Radiation is carried on very rapidly on bright moonlight nights; in consequence of which *dew* is very plentifully *deposited* on young plants, which conduces much to their growth and vigor.

1091 *Why is the air in immediate contact with the earth, on a clear night, cooler than the air at a little distance from the surface?*

Because it parts with its heat to the earth, which in turn loses it by radiation.

1092 *How can a thin covering of bass, or even muslin, protect trees from frost?*

Because *any covering* prevents the radiation of heat from the tree; and if trees are *not cooled down* by radiation, the vapor of the air will *not be frozen* as it comes in contact with them.

Bass—a kind of matting used by gardeners.

1093 *Why is the bass or canvas itself (which covers the tree) always drenched with dew?*

Because it *radiates heat* both *upwards* and *downwards;* in consequence of which it is *so cooled down* that it readily *chills the vapor* of the *air* into *dew*.

1094 *What is the cause of mist or earth-fog?*

If the *night* has been very *calm*, the radiation of heat from the earth has been very abundant; in consequence of which the *air* (resting on the earth) has been *chilled*, and its vapor condensed into a thick mist.

1095 *Why does not the mist become dew?*

Because the chill of the air is so *rapid*, that vapor is condensed *faster* than it can be *deposited* and (covering the earth as a mist) prevents any farther *radiation of heat* from the earth.

1096 *When the earth can no longer radiate heat upwards, does it continue to condense the vapor of the air?*

No; the air (in contact with the earth) becomes about equal in *temperature* with the surface of the earth itself;

for which reason the mist is not *condensed* into *dew*, but remains *floating* above the *earth* as a thick cloud.

1097 *This mist seems to rise higher and higher, and yet remains quite as dense below as at first: explain the cause of this.*

The air resting on the *earth* is first chilled, and *chills* the air resting on *it;* the air which touches this *new layer* of mist being *also* condensed, layer is added to layer; and thus the mist seems to be *rising*, when (in fact) it is only *deepening.*

1098 *Why do mist and dew vanish as the sun rises?*

Because the air becomes *warmer* at sunrise, and *absorbs* the vapor.

1099 *Can the dew properly be said to "fall?"*

Now; dew is always *formed upon the surface* of the material upon which it is found, and does not fall from the atmosphere.

1100 *Does the color of an object influence the deposition of dew?*

It does to a *considerable extent.*

1101 *How can this be shown?*

If we take pieces of red, black, green, and yellow glass, and expose them when the dew is condensing, we shall find that moisture will show itself *first* on the *yellow* and then on the *green glass*, but that *none* will appear on the *red* or *black* glass. The same thing will take place if we expose colored fluids in white glass bottles.

1102 *Why is the deposition of dew rarely observed in the close and sheltered streets of cities?*

Because there the objects are necessarily exposed to each other's radiation, and an *interchange of heat* takes place, which maintains them at a temperature *uniform with the air.*

1103 *When is dew converted into frost?*

If the temperature of the earth, or of the vessel, sink to the freezing point or below, the moisture will be deposited as before; but by freezing, it assumes the solid form, and is called frost.

1104 *Why is a dew-drop round?*

Because every part of it is *equally balanced;* and therefore there is no cause why *one part* of the drop should be farther from the centre than *another.*

1105 *Why will dew-drops roll about cabbage plants, poppies, &c., without wetting the surface?*

Because the leaves of cabbages and poppies are covered with a very *fine waxen powder*, over which the dew-drop rolls without wetting the surface, as a drop of rain would over dust.

1106 *Why does not a drop of rain wet the dust over which it rolls?*

Because dust has no *affinity* for water, and therefore repels it.

1107 *Why can swans and ducks dive under water without being wetted?*

Because their feathers are covered with an *oily secretion*, which has no affinity for water, and therefore repels it.

1108 *What is the figure which water always assumes when unsupported, or supported on a surface having little attraction for it?*

The figure of a *sphere.* This figure becomes more or less globular or spheroidal in its shape, as the attraction of the substances upon which it is received increases or diminishes?

1109 *What is the form of a drop of rain when descending in the air?*

A *sphere.*

1110 *Why should drops of water, resting upon surfaces which have no affinity for them, assume a spheroidal shape?*

Because such surfaces not having so great an attraction for the drops of water as the particles of water have for each other, the drops tend to preserve, as nearly as possible, the *spheroidal form* which they would have if entirely unsupported, as when falling as drops of rain.

1111 *Is dew ever formed upon the surface of water?*

The formation of dew upon ships which traverse the vast solitudes of the ocean has *never been noticed;* and it has been ascertained by experiment that even a small quantity of water gains no weight by exposure during a single night.

Although dew does not appear upon ships at a great distance from land, it is freely deposited on the same vessels arriving in the vicinity of *terra firma.* Thus, navigators who proceed from the Straits of Sunda to the Coromandel coast, know that they are near the end of the voyage when they perceive the ropes, sails, and other objects placed on the deck become moistened with dew during the night.

1112 *Why does not dew form upon the surface of water?*

Because whenever the aqueous particles at the surface are cooled, they become *heavier* than those below them, and *sink*, while warmer and lighter particles rise to the top. These, in their turn, become heavier, and descend; and the process, continuing throughout the night, maintains the surface of the water and the air at nearly the *same temperature.*

1113 *Is the temperature at which dew is deposited from the air always the same?*

No; when the air is saturated with moisture, a slight reduction of temperature occasions a deposition of dew; but when the air is very dry, a greater reduction of temperature is necessary to condense its vapor.

1114 *Why are the exposed parts of the human body never covered with dew?*

Because the *vital heat*, varying from 96° to 98° Fahrenheit, effectually *prevents* such a loss of warmth as is necessary to its production.

1115 *In what countries are the dews most copious and abundant?*

In *tropical climates.*

1116 *What is the reason of this?*

Because in those countries there is the greatest difference between the *temperature of the day* and that of the *night.*

The development of vegetation is greatest in tropical countries, and a great part of the nocturnal cooling is due to the leaves, which present to the sky an immense number of thin bodies, having large surface, well adapted to radiate heat.

CHAPTER VI

REFLECTION, ABSORPTION, AND TRANSMISSION OF HEAT.

1117 *What is meant by the reflection of heat?*

Heat is said to be reflected when it is caused to *rebound* or be *thrown back* from the surface of a reflecting body.

1118 *What are the best reflectors of heat?*

All *bright* surfaces and *light colors.*

1119 *Are good absorbers of heat good reflectors also?*

No; those things which *absorb* heat *best reflect* heat *worst;* and those which *reflect* heat *worst absorb* it *best.*

1120 *Why are those things which absorb heat unable to reflect it?*

Because if anything *sucks in heat*, as a sponge does water, it cannot *throw it off* from its surface; and if anything *throws off heat* from its surface, it cannot *drink it in.*

1121 *Why are reflectors always made of light-colored and highly-polished metal?*

Because *light-colored* and *highly-polished metal* makes the best of all reflectors.

1122 *If metal be such an excellent conductor of heat, how can it reflect heat, or throw it off?*

Polished metal is a *conductor of heat* only when that heat is communicated by *actual contact;* but whenever heat falls upon bright metal *in rays*, it is *reflected back again*, and the metal remains *cool.*

1123 *What is meant "by heat falling upon metal in rays," and not "by contact?"*

If a piece of metal were thrust *into* a fire, it would be *in actual contact with the fire;* but if it were *held before a fire*, the heat of the fire would fall upon it *in rays.*

1124 *Why will a kettle be slower in boiling if the bottom and sides are clean and bright?*

Because *bright* metal does *not absorb heat,* but *reflects* it; and (as the heat is *thrown off* from the surface of *bright* metal by reflection) therefore a new kettle takes a longer time to boil.

Reflects heat—that is, throws it off.

1125 *Why do persons wear white dresses in summer-time?*

Because white *throws off the heat* of the sun by *reflection,* and is a very bad absorbent of heat; in consequence of which white dresses never become *so hot from the scorching sun* as dark colors do.

1126 *Why do persons not wear white dresses in winter-time?*

Because *white will not absorb heat* like black and other dark colors; and therefore *white dresses are not so warm as dark* ones.

1127 *Why are shoes hotter for being dusty?*

Because dull, dusty shoes will *absorb heat* from the sun, earth, and air; but shoes brightly polished *throw off* the heat of the sun by reflection.

1128 *Why do not the solar rays, even in the hottest day, melt the snow upon the tops of high mountains, which are nearer to the sun than the level portions of the earth?*

Because they only heat those bodies which can *absorb their warmth,* as the rough surface of the earth. The snow is indeed struck by the rays of the sun, but being a white and shining body, it *reflects them,* and remains cold.

1129 *Why does it always freeze on the top of a high mountain?*

1. Because air is heated by *contact with the earth's surface* more than by solar rays which pass *through* it: as a mountain-top affords very small surface for such contact, it remains intensely cold; and

2. When air flows up the side of a mountain, it *expands* from diminished pressure; and consequently absorbs heat from surrounding objects.

Rarefied air can hold more latent heat than dense air can.

1130 *What is the difference between conducting heat and absorbing heat?*

To *conduct* heat is to *transmit it* from one body to another through a *conducting* medium. To *absorb* heat is to *suck it up*, as a sponge sucks up water.

1131 *Give me an example?*

Black cloth absorbs, but does not *conduct heat;* thus, if black cloth be laid in the sun, it will *absorb the rays* very rapidly; but if *one end* of the black cloth be made hot, it would not *conduct* the heat to the *other* end.

1132 *Are good conductors of heat good absorbers also?*

No; every *good conductor* of heat is a *bad absorber* of it; and *no good absorber* of heat can be a *good conductor* also.

1133 *Is iron a good absorber of heat?*

No; *iron* is a *good conductor*, but a very *bad absorber* of heat.

1134 *If a piece of brown paper be submitted to the action of a burning-glass it will catch fire much sooner than a piece of white paper would: explain the reason.*

Because *white* paper *reflects* the rays of the sun, or throws them back; in consequence of which it appears more luminous, but is not so much heated as dark *brown* paper, which *absorbs* the rays, and readily becomes heated to ignition.

1135 *How does the ceaseless change of air tend to decrease the warmth of a naked body?*

The air (which cases the body) absorbs as much heat from it as it can, while it remains in contact; being then blown away, it makes room for a *fresh coat of air*, which readily absorbs *more* heat.

1136 *Does the air which encases a naked body become (by contact) as warm as the body itself?*

It would do so, if it remained *motionless;* but, as it remains only a *very short time*, it absorbs as much heat as it can in the time, and passes on.

1137 *Why does fanning the face in summer make it cool?*

Because the fan *puts the air in motion*, and makes it pass more *rapidly over the face;* and (as the temperature of the *air is usually lower* than that of the human *face*) each volume of air *carries off some portion of its heat.*

1138 *Does a fan cool the air?*

No; it makes the air *hotter* by imparting to it the heat *out of our face;* but it cools our *face* by transferring its heat to the *air.*

1139 *How does fanning the face increase the heat of the air?*

By driving the air more rapidly over the human body, and causing it, consequently, to *absorb more heat.*

1140 *If fanning makes the air hotter, why can it make a person feel cooler?*

Because it takes the heat *out of the face*, and gives it to the *air.*

1141 *Why does wind generally feel cool?*

Because it drives the air more rapidly over our body, and this rapid *change* of air draws off a large quantity of heat.

1142 *Why does air absorb heat more quickly by being set in motion?*

Because every fresh gust of air *absorbs a fresh portion of heat;* and the more rapid the *succession of gusts*, the greater will be the quantity of heat absorbed.

1143 *If the air were hotter than our body would the wind feel cool?*

No; the air would feel *insufferably hot*, if it were *hotter than our body.*

1144 *Why would the air feel intensely hot, if it were warmer than our body?*

Because it would *add* to the heat of our body, instead of *diminishing it.*

1145 *Is the air ever as hot as the human body?*

In the extreme of summer the temperature of the air sometimes exceeds the natural temperature of the body; and when that is the case, the heat is almost insupportable.

1146 *Why does a kettle boil faster when the bottom and sides are covered with soot?*

Because the *black soot absorbs heat* very quickly from the fire, and the metal *conducts* it to the water.

1147 *Why do we wear white linen and a black outer dress, if we want to be warm?*

Because the *black outer dress* quickly *absorbs heat* from the sun; and the *white linen* (being a *bad* absorbent) abstracts no heat from the warm body.

1148 *What colors are warmest for dresses?*

For *outside* garments *black* is the *warmest*, and then such colors as approach nearest to black (as dark blue and green). *White is the coldest color* for external clothing.

1149 *Why are dark colors (for external wear) so much warmer than light ones?*

Because *dark colors absorb heat* from the sun more abundantly than *light* ones.

1150 *How can you prove that dark colors are warmer than light ones?*

If a piece of *black* and a piece of *white* cloth were laid upon snow, in a few hours the *black cloth will have melted the snow beneath;* whereas the *white* cloth will have produced little or *no effect upon it at all.*

The *darker* any color is, the *warmer* it is, because it is a better absorbent of heat. The order may be thus arranged: 1, black (warmest of all); 2, violet; 3, indigo; 4, blue; 5, green; 6, red; 7, yellow; and 8, white (coldest of all).

1151 *Why does the black skin of a negro never sunburn or blister with the hot sun?*

Because the *black color absorbs* the heat, conveys it *below the surface* of the skin, and converts it into *sensible heat* and *perspiration.*

1152 *Why does the white European skin blister and burn when exposed to the hot sun?*

Because *white will not absorb* heat; and therefore the hot sun *rests on the surface of the skin*, and *burns it.*

1153 *Why do most of the animals inhabiting the frigid zones have white fur, hair, or feathers?*

Because white *radiates* and *absorbs* but little heat.

1154 *What relation exists between the power of bodies to absorb and communicate heat?*

Those bodies which *absorb* heat *freely*, also *part with it most rapidly;* that is, they are sooner heated and more speedily cooled than other bodies.

1155 *At what temperature do metals burn when handled?*

Metals cannot be handled when raised to a temperature of more than *one hundred and twenty degrees.*

1156 *At what temperature does water scald?*

At *one hundred and fifty degrees.*

1157 *To what extent can the human system sustain the influence of heated air?*

Workmen enter ovens, in the manufacture of moulds of plaster of Paris, in which the thermometer *stands* 100° *above the temperature of boiling water*, and sustain no injury.

If the person so entering a heated oven should hold next to his skin a piece of metal, the latter would absorb heat with sufficient rapidity to burn the surface with which it was in contact.

1158 *Why is there so great a difference between the burning temperature of metals and air?*

The metals absorb heat *quickly*, and part with it *freely;* the air absorbs heat *very slowly*, and does not readily part with it.

1159 *What class of bodies allow heat to pass freely through them?*

Transparent bodies of little density, as the air, the various gases, etc., etc.

CHAPTER VII.

EFFECT OF HEAT.

1160 *What effect has heat upon substances generally?*

It *expands* them, or enlarges their dimensions.

1161 *Are the dimensions of every kind of matter regulated by heat?*

They *are;* its increase, with few exceptions, separates the particles of bodies to a greater distance from each other, producing *expansion*, so that the same quantity of matter is thus made to occupy a larger space; the diminution of heat has an opposite effect.

The expansion of solids by heat is clearly shown by the following experiment, *Fig.* 40: *m* represents a ring of metal, through which, at the ordinary temperature, a small iron or copper ball, *a*, will pass freely, this ball being a little less than the diameter of the ring. If this ball be now heated by the flame of an alcohol lamp, it will become so far expanded by heat as no longer to pass through the ring.

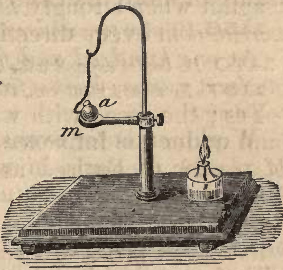


Fig. 40.

1162 *Is the form of bodies dependent on heat?*

It is.

1163 *How is this shown?*

By the increase of heat, *solids* are converted into *liquids*, and *liquids* are dissipated into *vapor;* by its decrease, vapors are *condensed* into liquids, and these become solid.

1164 *If matter ceased to be influenced by heat, what would be the effect?*

All liquids, vapors, and doubtless even gases, would become permanently *solid*, and all *motion* on the surface of the earth would be *arrested.*

1165 *What are the three most apparent effects of heat, so far as relates to the form and dimensions of bodies?*

Expansion, *liquefaction*, and *vaporization.*

1166 *Does heat expand air?*

Yes; if a bladder (partially filled with air) be tied up at the neck, and *laid before the fire*, the air will *expand* till the bladder *bursts.*

1167 *Why will the air swell if the bladder be laid before the fire?*

Because the heat of the fire will drive the particles of air *apart from each other*, and cause them to occupy more room than they did before.

1168 *Does heat expand all matter?*

Yes; *every* thing (that man is acquainted with) is expanded by heat.

1169 *How can we prove that solids expand with heat?*

If we take the *exact dimensions* in length, breadth, and thickness of any substance when *cold*, and measure it again when strongly *heated*, it will be found to have *increased* in every direction.

1170 *Do bodies expand with the increase of heat, and contract upon its withdrawal, with any degree of force?*

Yes; the force with which bodies contract and expand under the influence of heat is *apparently irresistible*, and is recognised as one of the *greatest forces in nature.*

1171 *What peculiarity exists in the effect of heat upon the bulk of some fluids?*

That at a certain temperature *increase of heat* causes them to *contract*, and its *diminution* makes them *expand.*

1172 *What classes of liquids exhibit this peculiarity?*

Those only which increase in bulk in passing from the *liquid to the solid state*, and this change is remarked *only* within a few degrees of temperature above their point of congelation.

1173 *What is a noted example of this exception to the general laws of heat?*

Water; ice swims upon the surface of water, and therefore must be lighter, a convincing proof that water in the act of freezing must *expand.*

1174 *Why is the ice produced by the freezing of sea water always fresh and free from salt?*

Because water, in freezing, if in sufficient quantity to allow freedom of motion to its particles, *expels all impurities and coloring matters.*

1175 *If a solution of indigo be frozen, why will the ice formed be clear and colorless?*

Because the water in which the indigo was dissolved expels all the blue coloring matter while freezing.

1176 *Why are blocks of ice generally filled with air-bubbles?*

Because the water, during the act of freezing, *expels the air* contained in it, and many of the liberated bubbles become lodged and imbedded in the thickening fluid.

1177 *Is the force created by the expansion of water in the act of freezing very great?*

Yes; as an illustration the following experiment may be quoted: Cast-iron bomb-shells, thirteen inches in diameter and two inches thick, were filled with water, and their apertures or fuse-holes firmly plugged with iron bolts. Thus prepared, upon exposure to the severe cold of a Canadian winter, about 19° below "zero," at the moment the water froze, the iron plugs were violently thrust out, and the ice protruded, and in some instances the shells burst asunder, thus demonstrating the enormous interior pressure to which they were subjected by water assuming the solid state.

1178 *What is the principal cause of the rounded and weather-worn aspect of some rocks, especially the limestone and sandstone rocks?*

The *expansion of freezing water:* water is absorbed into their fissures and pores by capillary attraction, and when it freezes during winter, it expands and detaches successive fragments, so that the original sharp and abrupt outline is gradually rounded and softened down.

1179 *Why, in the winter, do we let the water run to prevent its freezing in the service pipe?*

Because the *motion of the water* prevents the crystals of ice from forming or attaching themselves to the sides of the pipe.

1180 *Can a lens be made of ice capable of concentrating the rays of the sun with sufficient intensity to inflame substances?*

Yes; a *burning-lens* can be formed of transparent ice, of power sufficient to produce effects nearly equal to those of the glass lens.

1181 *What is "ground ice," or "anchor ice?"*

Ice formed at the *bottom of streams or rivers.*

1182 *Upon what does the formation of icicles depend?*

Upon the *successive congelation of drops* or slender streams of water.

1183 *What is ice?*

Frozen water. When the temperature of water under ordinary circumstances is reduced to 32° of heat, water will no longer remain in a fluid state.

1184 *Can water be cooled below* 32°, *under any circumstances, without freezing?*

If pure, *recently-boiled water*, be cooled *very slowly* and kept *very tranquil*, its temperature may be lowered to 21° without the formation of ice; but the least motion causes it to congeal suddenly, and its temperature rises to 32°.

1185 *Why is solid ice lighter than water?*

Because water *expands* by freezing; and as its *bulk* is *increased*, its *specific gravity* must be *less*.

Nine cubic inches of water become *ten* when frozen.

1186 *Why are earthen or porcelain water vessels apt to break in a frosty night?*

Because the water in them *freezes*, and (*expanding* by frost) bursts the vessels to make room for its increased volume.

1187 *Why does it not expand upwards (like boiling water) and run over?*

Because the *surface* is frozen first; and the frozen surface acts as a *plug*, which is more difficult to burst than the earthen vessel itself.

1188 *Why do tiles, stones, and rocks often split in winter?*

Because the moisture in them *freezes*, and (expanding by frost) *splits the solid mass.*

1189 *In winter-time, footmarks and wheel-ruts are often covered with an icy network, through the interstices of which the soil is clearly seen: why does the water freeze in the form of network?*

Because it freezes first at the *sides* of the footprints; other crystals gradually shoot across, and would cover the whole surface, if the earth did not *absorb* the water before it had time to freeze.

1190 *In winter-time, these footmarks and wheel-ruts are sometimes covered with a perfect sheet of ice, and not an icy network: why is this?*

Because the *air is colder* and the *earth harder* than in the former case; in consequence of which the *entire surface* of the footprint is frozen over before the earth has had time to absorb the water.

1191 *Why is not the ice solid in these ruts?—why is there only a very thin film or network of ice?*

Because the earth *absorbs most of the water*, and leaves only the icy *film behind.*

1192 *Why do water-pipes frequently burst in frosty weather?*

Because the water in them *freezes*, and (*expanding by frost*) bursts the pipes to make room for its increased volume.

1193 *Why does the earth crack in intense cold weather?*

The moisture in the soil in the act of freezing *expands*, and forces the particles asunder. The disruption of the earth is frequently accompanied with a loud sound.

1194 *Does not water expand by heat as well as by cold?*

Yes; it expands as soon as it is more than 42°, *till it boils;* after which time it flies off in steam.

1195 *When does water begin to expand from cold?*

When it is reduced to 40°. Water is wisely ordained to be an *exception* to a very general rule: it *contracts* till it is reduced to 40°, and then it *expands till it freezes.*

The general rule is this:—That cold *condenses* and *contracts* the volume of nearly everything; but water is *not contracted* by cold when it freezes (which it does at 32°).

1196 *Why does water expand when it freezes?*

The expansion of water at the moment of freezing is attributed to a new and peculiar arrangement of its particles. Ice is, in reality, *crystallized water*, and during its formation the particles arrange themselves in ranks and lines which cross each other at angles of 60° and 120°, and consequently occupy more space than when liquid. This may be seen by examining the surface of water in a saucer while freezing.

1197 *Why is the bottom of a river rarely frozen?*

Because water *ascends* to the surface as soon as it becomes colder than 42°, and (if it freezes) *floats there* till it is melted.

1198 *Show the wisdom of the Creator in this wonderful exception to a general law.*

If ice were *heavier than water* it would *sink*, and a river would soon become a *solid block of ice*, which could never be dissolved.

The general rule is, that all substances become *heavier* from condensation; but ice is *lighter* than water.

1199 *Why does not the ice on the surface of a river chill the water beneath, and make it freeze?*

1. Because water is a *very bad conductor*, and is heated or chilled by *convection* only;

2. If the ice on the surface were to communicate its *coldness* to the water beneath, the water beneath would communicate its *heat to the ice*, and the ice would instantly *melt*; and

3. The ice on the surface acts as a *shield*, to prevent the cold from *penetrating through the river* to freeze the water below the surface.

1200 *Why does water freeze at the surface first?*

Because the surface is in *contact with the air*, and the air *carries away its heat*.

1201 *Why does the coat of ice grow thicker and thicker if the frost continues?*

Because the *heat* of the water (immediately below the frozen surface) *passes through the ice* into the *cold air*.

1202 *Why are not whole rivers frozen (layer by layer) till they become solid ice?*

Because water is so *slow* a conductor, that our frosts never continue *long enough* to convert a whole river into a solid mass of ice.

1203 *Why does not running water freeze as fast as still water?*

1. Because the motion of the current *disturbs the crystals*, and prevents their forming into a continuous surface; and

2. The heat of the *under* surface is communicated to the *upper* surface by the *motion of the water*.

1204 *When running water is frozen, why is the ice generally very rough?*

Because little flakes of ice are first formed and *carried down* the stream, till they meet some *obstacle* to *stop* them; *other* flakes of ice (impinging against them) are arrested in like manner; and the *edges* of the different flakes *overlapping* each other, *make the surface rough.*

1205 *Why do some parts of a river freeze less than others?*

Because *springs* issue from the bottom, and (as they bubble upwards) *thaw the ice*, or make it thin.

1206 *When persons fall into a river in winter-time, why does the water feel remarkably warm?*

Because the *frosty air* is at least ten or twelve degrees *colder* than the water is.

The water below the surface is at least 42°, but the air 32°, or even less.

1207 *Why is sea water rarely frozen?*

1. Because the *mass of water is so great*, that it requires a very long time to cool the whole volume down to forty degrees;

2. The *ebb and flow* of the sea interfere with the cooling influence of the air; and

3. *Salt* water never freezes till the surface is cooled down to *twenty-seven degrees*, or five degrees below the freezing point of fresh water.

1208 *Why do some lakes rarely (if ever) freeze?*

1. Because they are *very deep;* and

2. Because their water is supplied by *springs* which bubble from the bottom.

1209 *How does the depth of water influence its freezing?*

It is necessary that the *whole volume of water* should be reduced to forty degrees before the *surface will begin to freeze;* and the *deeper* the water, the *longer* it will be before the whole volume is thus reduced.

1210 *Why do springs at the bottom of a lake prevent its freezing?*

Because they keep continually sending forth water having a temperature *above that of the mass of the water*, which prevents the lake from being reduced to the necessary degree of coldness.

1211 *It is more chilly in a thaw than in a frost: explain the reason of this.*

When frozen water is *thawed*, it *absorbs* heat from the *air*, etc., to melt the ice ; in consequence of which the heat of the air is greatly reduced.

1212 *To what extent can the temperature be reduced by the liquefaction of a mixture of the two solids, snow and salt?*

By means of a mixture of equal weights of common salt and fresh snow (or pounded ice), a steady temperature of nearly 40° below the freezing point of water can be maintained for hours.

1213 *How much heat is required to melt ice?*

The conversion of a cube of ice, three feet on the side, into water at 32°, would absorb all the heat produced by the combustion of a bushel of coal.

1214 *Why does the frost of winter make the earth in spring loose and friable?*

Because the *water* absorbed by the earth in warm weather, *expanding by the frost*, thrusts the particles of earth apart from each other, and leaves a chink or crack between.

1215 *Show the wisdom of the Creator in this arrangement.*

These *cracks* in the earth let in air, dew, rain, and many gases favorable to vegetation.

1216 *Why are delicate trees covered with straw in winter?*

Because straw (being a non-conductor) prevents the *sap of the tree* from being frozen.

1217 *What is hoarfrost?*

There are two sorts of hoarfrost: 1. *Frozen dew ;* and 2. *Frozen fog.*

1218 *What is the cause of the ground hoarfrost, or frozen dew?*

Very *rapid radiation* of heat from the earth ; in consequence of which the *surface* is so *cooled down*, that it *freezes the dew* condensed upon it.

1219 *Why is hoarfrost seen only after a very clear night?*

Because the earth will not have thrown off heat enough by radiation to *freeze* the vapor condensed upon its surface, unless the night be very clear indeed.

1220 *What is the cause of that hoarfrost which arises from frozen fog?*

The thick fog which invested the earth during the night (being condensed by the *cold frost* of early morning) is *congealed* upon *every object* with which it comes in contact.

1221 *Why is there little or no hoarfrost under shrubs and shady trees?*

1. Because the leafy top *arrests* the process of radiation from the earth; and

2. Shrubs and trees radiate *heat* towards the earth; and therefore the *ground beneath* is rarely *cold enough* to *congeal* the little dew which rests upon it.

1222 *Why does hoarfrost very often cover the ground and trees, when the water of rivers is not frozen?*

Because it is not the effect of cold in the *air*, but cold on the surface of the *earth* (produced by excessive radiation), which *freezes the dew* condensed upon it.

1223 *Why is the hoarfrost upon grass and vegetables much thicker than that upon lofty trees?*

Because the air (resting on the *surface* of the ground) is much colder after sunset than the *air higher up;* in consequence of which more *vapor* is *condensed* and *frozen* there.

1224 *What is the cause of the pretty frostwork seen on bedroom windows in winter-time?*

The *breath* and insensible *perspiration* of the sleeper (coming in contact with the ice-cold window) are *frozen* by the cold glass, and, crystallizing, form those beautiful appearances seen on a winter morning.

1225 *Are all the figures of frostwork formed in accordance with certain fixed laws?*

All these figures are *limited by certain laws*, and the lines which bound them form among themselves no angles but those of 30°, 60°, and 120°.

1226 *If you fracture thin ice by allowing a pole or weight to fall upon it, will the lines of the fracture have anything of regularity?*

Yes; the fracture will generally present a *star* with *six equidistant radii*, or angles of 60°.

1227 *Why is a glass or earthen vessel apt to break when hot water is poured into it?*

Because the *inside* of the glass is expanded by the hot water, and *not the outside;* so the *glass snaps* in consequence of this unequal expansion.

1228 *Why is not the outside of the glass expanded by the hot water as well as the inside?*

Because glass is a *bad conductor of heat*, and *breaks* before the heat of the *inner* surface is conducted to the *outside.*

1229 *Why does a glass snap because the inner surface is hotter than the outer?*

Because the *inner* surface is expanded, and not the *outer;* in consequence of which an *opposing force* is created which breaks the glass.

1230 *Why does a cooper heat his hoops red hot when he puts them on a tub?*

1. As *iron expands by heat*, the hoops will be *larger* when they are red hot; in consequence of which they will fit on the tub *more easily;* and

2. As *iron contracts by cold*, the hoops will *shrink* as they cool down, and girt the tub with a *tighter grasp.*

1231 *Why does a wheelwright make the tire red hot which he fixes on a wheel?*

1. That it may *fit on more easily;* and
2. That it may *girt the wheel more tightly.*

1232 *Why will the wheelwright's tire fit the wheel more easily for being made red hot?*

Because it will be *expanded* by the heat, and (being larger) will go on the wheel more *easily.*

1233 *Why will the tire which has been put on hot girt the wheel more firmly?*

Because it will *shrink* when it cools down, and therefore *girt the wheel with a tighter grasp.*

1234 *Why does a stove make a crackling noise when a fire is very hot?*

Because it *expands* from the heat; and the parts of the stove *rubbing* against each other, or driving against the *bricks*, produce a *crackling* noise.

1235 *Why does a stove make a similar crackling noise when a large fire is put out?*

Because the metal of the stove contracts, by reason of a reduction of temperature, when the fire is extinguished.

1236 *Why are the nails in almost all old houses loose and easily drawn out?*

Because the iron *expands* in the *summer*, and *contracts* in the *winter*, more than the stone or wood, and thus the opening is gradually enlarged after a lapse of time.

1237 *Why does a piano give a higher tone in a cold than in a warm room?*

Because in a cold room the strings are *contracted and tighter.*

1238 *Why do clocks go slower in summer and faster in winter?*

Because the *pendulums elongate* in summer through the effects of heat, and consequently vibrate slower; while in *winter they contract*, become shorter, and vibrate more rapidly.

1239 *How is this inequality in the rate of motion in timepieces obviated?*

By what is called a *compensating pendulum;* that is, one constructed of two metals, possessing different expansive powers, in such a manner that the greater expansion of one bar in one direction equals the less expansion of other bars in a different direction, and thus maintain an invariable length of the pendulum.

1240 *Does wood expand under the influence of heat differently from metal?*

Yes; an iron bar expands and contracts equally in all directions, but wood expands and contracts more in *breadth* than in *length.*

1241 *Why will a person, buying oil, molasses, spirits, etc., by the measure, get a greater weight of the same material in the same measure in the winter than in the summer?*

Because these liquids *contract* and occupy *less space* in the winter than in summer; consequently it requires more of the same kind to fill the same space in winter than in summer.

1242 *How can heat be measured?*

Only by its *effects:* since the magnitude of any body changes with the heat to which it is exposed; and since, when subject to the same calorific influences, it always has the same magnitude, these dilatations and contractions, which are the constant effects of heat, may be taken as the measure of the physical cause that produced them.

1243 *What is the temperature of a body?*

It is the *actual state* of a body at any moment, determined by a comparison of its magnitude with the heat to which it is exposed.

1244 *What is a change of temperature?*

The change in *magnitude* which a body suffers by changes in the *heat* to which it is exposed.

1245 *What are the instruments for measuring heat called?*

Thermometers and *pyrometers.*

1246 *What is the difference between them?*

A *thermometer* is used for measuring *moderate temperatures;* while the *pyrometer* is chiefly applied to determine the more *elevated degrees* of heat.

1247 *What substances are best adapted for measuring the effects of heat by their expansion and contraction?*

Liquids, above all other substances.

1248 *Why are liquids best adapted for this purpose?*

Because in solids the direct expansion by heat is so small as to be seen or measured with difficulty; in air or gases it is too extensive and too liable to be affected by atmospheric pressure; but liquids are free from both disadvantages.

1249 *What liquid is generally used for the construction of ordinary thermometers?*

Mercury or *quicksilver.*

1250 *What metal is distinguished from all others by its fluidity at ordinary temperatures?*

Mercury or *quicksilver.*

1251 *Does mercury, like other metals, expand by heat?*

It readily *expands* or *contracts* with *every variation* of temperature.

1252 *Why is mercury preferable to all other liquids for the purposes of the thermometer?*

Because it *boils* at a *higher temperature* than any other liquid, except certain oils; and, on the other hand, it *freezes* at a *lower temperature* than all other liquids, except some of the most volatile, such as ether and alcohol.

Thus, a mercurial thermometer will have a wider range than any other liquid thermometer. It is also attended with this convenience, that the extent of temperature included between melting ice and boiling water stands at a considerable distance from the limits of its range, or its freezing and boiling points.

1253 *Of what does the mercurial thermometer consist?*

The mercurial thermometer consists essentially of a glass tube with a bulb at one extremity, and which, having been filled with mercury at a certain temperature, introduced through the open end, has been hermetically sealed while full, so that no air can afterwards enter it.

As the tube and mercury in it gradually become cooled, the inclosed fluid contracts, and consequently sinks, leaving above it a vacant space or vacuum, through which it may again expand on the application of heat.

1254 *As thermometers are constructed of different dimensions and capacities, how are they graduated to indicate the same temperature under the same circumstances, as the freezing point, for example?*

The thermometers are first immersed in *melting snow* or *ice*. The mercury will be observed to stop in each thermometer-tube at a certain height; these heights are then marked upon the tubes. Now it has been ascertained that at whatever time and place the instruments may be afterwards immersed in melting snow or ice, the mercury contained in them will always fix itself at the point thus marked. This point is called the *freezing point* of water.

1255 *How is the boiling point ascertained?*

It has been found that at whatever time or place the instruments are immersed in pure water, when boiling, provided the barometer stands at the height of thirty inches, the mercury will always rise in each to a certain height. This, therefore, forms another *fixed point* on the geometric scale, and is called the *boiling point.*

1256 *How are the intermediate points determined?*

In Fahrenheit's thermometer, the intervals on the scale, between the freezing and boiling points, are divided into 180 equal parts. This division is similarly continued below the freezing point to the place 0, and each division upwards from that is marked with the successive number 1, 2, 3, etc. The freezing point will now be the 32d division, and the boiling point will be the 212th division. These divisions are called *degrees*, and the boiling point will therefore be 212°, and the freezing temperature, 32°.

1257 *When and by whom was the thermometer invented?*

The thermometer was invented about the year 1600; but, like many other inventions, the merit of its discovery is not to be ascribed to one person, but to be distributed among many.

1258 *Why is the thermometer in general use in the United States, England, and Holland, called Fahrenheit's thermometer?*

Because thermometers having a like graduation were first manufactured by Fahrenheit, a Dutch philosophical instrument-maker. The employment of mercury as the most suitable fluid for the thermometer is also usually attributed to him.

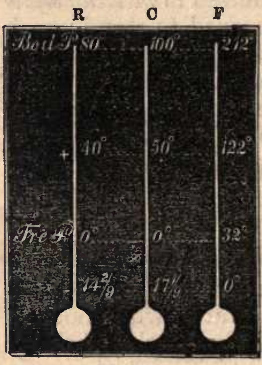


Fig. 41.

1259 *How many kinds of thermometers are in general use?*

Three: Fahrenheit's, *Reaumur's*, and the *Centigrade* thermometer, or thermometer of Celsius.

1260 *What constitutes the difference between these instruments?*

The differences of *graduation* between the freezing and boiling points of water. Reaumur is divided into *eighty* degrees, the Centigrade into *one hundred*, and Fahrenheit's into *one hun-*

dred and eighty. According to Reaumur, water freezes at 0°, and boils at 80°; according to Centigrade, it freezes at 0°, and boils at 100°; and according to Fahrenheit, it freezes at 32°, and boils at 212°; the last, very singularly, commences counting not at the freezing point, but 32° below it.

The differences between these instruments can be easily seen by reference to *Fig.* 41.

1261 *In what countries are the Reaumur and Centigrade thermometers generally used?*

Reaumur is in general use in *Germany*, and the *Centigrade* in *France;* but for scientific purposes the Centigrade is almost universally adopted.

1262 *At what temperature does mercury freeze?*

At about 39° *below the zero* of Fahrenheit's thermometer.

1263 *How are degrees of cold more intense than this measured?*

By using a thermometer filled with *alcohol* colored red, as this fluid when pure does not congeal at 100° Fahrenheit below zero.

1264 *At what temperature does mercury boil?*

At 660° Fahrenheit.

1265 *How are temperatures greater than this determined?*

By means of the *expansion of solids;* and instruments founded upon this principle are commonly called *pyrometers.*

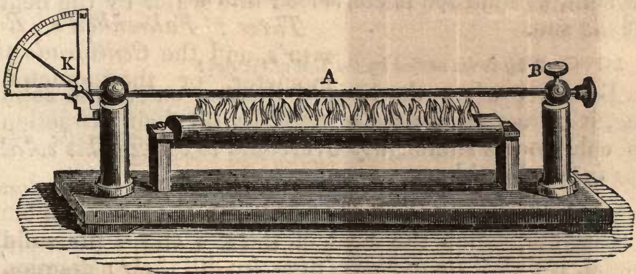


Fig. 42.

The construction of the pyrometer is represented in *Fig.* 42. A represents a metallic bar, fixed at one end, B, but left free at the other, and in contact with the end of a pointer, K, moving freely over a graduated scale. If the bar be heated by the flame of alcohol, the metal expands, and pressing upon the end of the pointer moves it, in a greater or less degree.

1266 *On what principle have pyrometers generally been constructed?*

On the *relative expansion* of bars of iron, or some other metal.

1267 *Does a thermometer inform us how much heat any body contains?*

No; it merely points out a *difference* in the *temperature* of two or more substances. All we learn by the thermometer is whether the temperature of one body is greater or less than that of another; and if there is a difference it is expressed numerically—namely, by the degrees of the thermometer.

It must be remembered that these degrees are parts of an arbitrary scale, selected for convenience, without any reference whatever to the actual quantity of heat present in bodies.

1268 *After the expansion of solids, when acted upon by heat, what other effect is next observed?*

They change their *original state*, become liquid, or melt. Many of them become *soft* before melting, so that they may be kneaded; for instance, wax, glass, and iron; in this condition, glass can be bent and moulded like wax, and iron can be forged or welded.

1269 *What is meant by liquefaction?*

The conversion of a *solid* into a *liquid* by the agency of heat, as solid ice is converted into water by the heat of the sun.

1270 *Why is ice melted by the heat of the sun?*

Because, when the heat of the sun enters the solid ice, it *forces its particles asunder*, till their attraction of cohesion is sufficiently overcome to *convert the solid ice into a liquid.*

1271 *Why are metals melted by the heat of fire?*

Because, when the heat of the fire enters the solid metal, it *forces its particles asunder*, till their attraction of cohesion is sufficiently overcome to *convert the solid metal into a liquid.*

1272 *When salt is mixed with water and disappears in the liquid, what is said to have taken place?*

The salt is said to have *dissolved* in the water, and the liquid is now a *solution of salt.*

1273 *What, then, is a solution?*

A solution is the result of an attraction or affinity between a solid and a fluid; and when a solid disappears in a liquid, if the compound exhibits *perfect transparency*, we have an example of a *perfect solution.*

1274 *When is a solution said to be saturated?*

When the fluid has dissolved as much of the solid as it is capable of doing, it is said to be *saturated;* or, in other words, the affinity or attraction of the fluid for the solid continues to operate to a certain point, where it is overbalanced by the cohesion of the solid; it then ceases, and the fluid is said to be *saturated.*

1275 *What is the difference between a solution and a mixture?*

A solution is a *chemical union;* a mixture is a mere *mechanical union* of bodies.

1276 *Why will water dissolve sugar?*

Because there is *attraction* or *affinity* between the particles of the water and the particles of the sugar.

1277 *What do we mean by affinity?*

Affinity is that kind of attraction in virtue of which bodies of a dissimilar character combine together into a whole, which appears perfectly uniform to the senses, even when assisted by powerful magnifying instruments.

1278 *Why will not water dissolve granite or metallic iron?*

Because there is not *sufficient affinity* or *attraction* between the particles of the water and those of the iron or granite.

1279 *Are there any liquids that have sufficient affinity to dissolve iron and granite?*

Yes; certain *acids* have so great an affinity for the iron and granite that they are enabled to dissolve them.

1280 *Why will not water dissolve oil?*

Because there is *no affinity* or attraction between the *particles* of the two substances.

1281 *Why will alcohol and ether dissolve oil?*

Because the *attraction* or *affinity* between the alcohol or ether and the oil is sufficient to enable them to effect a solution.

1282 *What effect has heat upon the dissolving power of liquids?*

In most cases the addition of *heat* to a liquid greatly increases its *solvent properties. Hot water* will dissolve much more sugar than cold water, and hot water will also dissolve many things which cold water is unable to affect.

1283 *Why does not wood melt like metal?*

Because the heat of the fire *decomposes* the wood into *gas*, *smoke*, and *ashes*, and the different parts *separate* from each other.

1284 *What is meant by vaporization?*

The *conversion* of a *solid* or *liquid into vapor;* as snow or water is converted into vapor by the heat of the sun.

1285 *Why is water converted into steam by the heat of the fire?*

Because, when the heat of the fire enters the water, it *separates its substance* into very *minute particles*, which (being lighter than air) fly off from the surface in the form of steam.

1286 *Why do doors swell in rainy weather?*

Because the *air is filled with vapor*, which (penetrating into the pores of the wood) *forces its particles farther apart*, and swells the door.

1287 *Why do doors shrink in dry weather?*

Because the *moisture is absorbed from the wood*, and, as the particles are *brought closer together*, the size of the door is *lessened;* in other words, the *wood shrinks.*

1288 *Why does a drop of water sometimes roll along a piece of hot iron without leaving the least trace?*

Because the *bottom* of the drop is changed into *vapor*, which *buoys the drop up*, without allowing it to touch the iron.

1289 *Why does it roll?*

Because the *current of air* (which is always passing over a heated surface) *drives it along.*

1290 *Why does a laundress put a little saliva on a flat-iron to know if it be hot enough?*

Because when the saliva *sticks* to the iron and is *evaporated*, she knows it is *not* sufficiently hot; but when it *runs along the iron*, it is.

1291 *Why is the flat-iron hotter if the saliva runs along it, than if it adheres till it is evaporated?*

Because when the saliva *runs along* the iron, the heat is sufficient to *convert the bottom of the drop into vapor;* but if the saliva *will not roll*, the iron is *not* sufficiently hot to convert the bottom of the drop into vapor.

1292 *To what substances do we apply the term "volatile?"*

To those which have a great tendency to *assume the gaseous form.*

1293 *To what substances do we apply the term "fixed," or "non-volatile?"*

To those in which the *tendency* to assume the gaseous form is *small.*

1294 *Do vapors occupy much more space than the substances from which they were produced?*

They occupy a much *greater space;* water, in passing from its point of greatest density into vapor, expands to *sixteen hundred and ninety-six times its volume.*

1295 *Under what two heads does the subject of vaporization divide itself?*

Into *ebullition* and *evaporation*

1296 *What is distillation?*

A process by which one body is *separated from another* by means of *heat*, in cases where one of the bodies assumes the form of vapor at a lower temperature than the other; this first rises in the form of vapor, which is received and condensed in a separate vessel.

1297 *How is the process of simple distillation effected?*

A peculiar-shaped vessel called a *retort* (*Fig.* 43) is half filled with a volatile liquid and heated; the steam, as it forms, passes through the neck of the retort into a *glass receiver* contained in a vessel filled with *cold water*, and is then *condensed.*

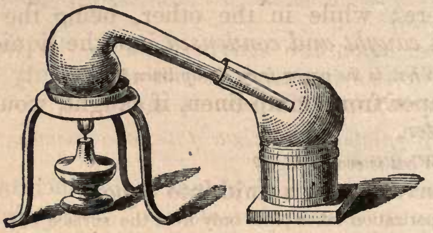


Fig. 43.

1298 *Why is water obtained in this manner by distillation purer than spring water?*

Because the non-volatile, earthy, and saline portions contained in all spring waters do not *ascend with the vapor*, but *remain in the retort.* By this means very volatile bodies can be easily separated from less volatile ones; as brandy and alcohol from the less volatile water which may be mixed with them.

1299 *When the vessel used for generating the vapor is very large, what is it called?*

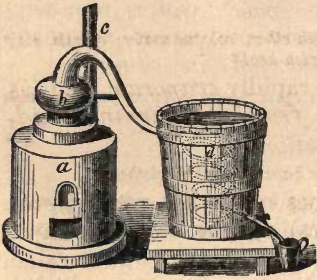


Fig. 44.

A "*still;*" and, for condensing the vapor, vats are constructed, holding serpentine pipes or "*worms,*" which present a greater condensing surface than if the pipe had passed directly through the vat.

To keep the coil of pipe cool, the vats are kept filled with cold water. (*See Fig.* 44.)

In this figure *a* is a furnace, in which is fixed a copper vessel to contain the fluid. Heat being applied, the steam rises in the head *b*, and passes through the worm *d*, which is placed in a vessel of water, the refrigerator. The vapor thus generated is condensed in its passage, and passes out as a liquid by the external pipe into a receiver.

1300 *What is the difference between drying by heat and distilling?*

In the one case, the substance vaporized, being of no use, is allowed *to escape* or become *dissipated* in the atmosphere; while in the other, being the valuable part, it is *caught and condensed* into the liquid form.

1301 *What is the vapor from damp linen?*

The vapor from damp linen, if caught, would be *distilled water.*

1302 *What is evaporation?*

The conversion of a fluid into *vapor.*

When vaporization takes place only from the surface of a body, either because the heat has access to that part, or because the evolution of vapor takes place through the medium of a gas or air already present, the action can only be recognised by the diminution of the bulk of the body: this phenomenon is called evaporation.

1303 *What effects are produced by evaporation?*

The substance vaporized *absorbs heat* from the body whence it issues; and the body, *deprived of a portion of its substance* by evaporation, *loses heat.*

1304 *If you wet your finger in your mouth, and hold it up in the air, why does it feel cold?*

Because the saliva quickly *evaporates*, and (as it evaporates) *absorbs heat from the finger*, making it feel cold.

1305 *If you bathe your temples with ether, cologne water, spirits, etc., why does it allay inflammation and feverish heat?*

Because these liquids very rapidly *evaporate*, and (as they evaporate) *absorb heat from the burning head*, producing a sensation of cold.

1306 *Why do we feel cold when we have wet feet or clothes?*

Because the wet of our shoes or clothes rapidly *evaporates*, and (as it evaporates) *absorbs heat from our body*, which makes us feel cold.

1307 *Why do wet feet or clothes give us "cold?"*

Because the evaporation *absorbs heat* so abundantly from the surface of our body, that its temperature is *lowered below its natural standard;* in consequence of which health is injured.

1308 *Why is it dangerous to sleep in a damp bed?*

Because the heat is continually absorbed from the surface of our body to *convert the damp of the sheets into vapor;* in consequence of which our animal heat is reduced *below the healthy standard.*

1309 *Why is health injured when the temperature of the body is reduced below its natural standard?*

Because the *balance of the circulation* is destroyed. Blood is driven away from the *external surface* by the *chill*, and thrown upon the *internal organs*, which are *oppressed* by this increase *of blood.*

1310 *Why do we not feel the same sensation of cold if we throw a waterproof coat over our wet clothes?*

Because water-proof coats (being air-tight) *prevent evaporation*, and (as the *wet cannot evaporate*) no heat is absorbed from our bodies.

1311 *Why does sprinkling a hot room with water cool it?*

Because the heat of the room causes a *rapid evaporation of the sprinkled water*, and as the water evaporates, *it absorbs heat from the room*, which cools it.

1312 *Why does watering the streets and roads cool them?*

Because they part with their heat *to promote the evaporation of the water sprinkled on them.*

1313 *Why does a shower of rain cool the air in summer-time?*

Because the wet earth *parts with its heat to promote evaporation;* and when the *earth* is cooled, it *cools the air* also.

1314 *Why is linen dried by being exposed to the wind?*

Because the wind *accelerates evaporation* by removing the vapor from the *surface of the wet linen* as fast as it is formed.

1315 *Why does draining land promote warmth*

Because abstracting water *diminishes evaporation;* in consequence of which *less heat* is withdrawn from the earth.

1316 *Why does cultivation increase the warmth of a country?*

A cultivated country is better drained, and laid open to the rays of the sun. The forests being cut down, the snow quickly disappears in the spring, and the earth soon becomes dry.

1317 *Why does bread after the lapse of a few days become dry and stale?*

Because the moisture contained in it evaporates; the particles then shrink, and the whole mass becomes hard.

1318 *Why is not the vapor of the sea salt?*

Because the *salt* is always *left behind* in the process of evaporation.

1319 *"All the rivers run into the sea:" why is not the sea full?*

Because the quantity of water *evaporated* from the surface of the sea is *equal* to the quantity *poured into it* by the rivers; therefore the sea is never full.

1320 *Why is it frequently cooler after a rain?*

Because water which falls from the atmosphere soon *returns to it* in the form of *vapor*, carrying with it, in the *latent form*, a large amount of *heat* taken from every object, thus moderating the temperature of the earth, and refreshing the animal and vegetable creations.

1321 *Does evaporation take place from the surface of snow and ice?*

Yes, to a very *considerable extent*, even when the temperature of the air is *below the freezing point.*

1322 *What is steam?*

The *vapor of boiling water.*

1323 *Is steam visible or invisible?*

Steam is *invisible;* but when it comes in contact with the air (being *condensed* into small drops) it instantly becomes visible.

1324 *How do you know that steam is invisible?*

If you look at the spout of a boiling kettle, you will find that the steam (which issues from the spout) is always invisible for about *half an inch*, after which it *becomes visible.*

1325 *Why is the steam invisible for half an inch?*

Because the air is not able to condense it, as it first issues from the spout; but when it *spreads* and comes in contact with a larger volume of air, the *invisible steam* is readily condensed into *visible drops.*

1326 *Does air ever exist without steam or vapor of water?*

Air without steam (theoretically called *dry air*) is *not known to exist in nature*, and is probably not producible by art.

1327 *Is the visible matter, popularly called steam, really true steam?*

By *no means*, and should be carefully distinguished from steam proper, or the aeriform state of water. The cloud or smoke-like matter alluded to is really not an air or vapor at all, but a dust-like cloud of minute bodies of *liquid* water, wafted by a current either of true steam, or, more frequently, of mere moist air.

1328 *Is it necessary to the production of steam that water should be raised to the boiling temperature?*

It is *not;* the surface of any watery liquid, *about* 20° *warmer than any superincumbent air* (however warm or cold that may be), rapidly gives off true *steam*, which is invisible, but which no sooner mixes with colder air than it is recondensed into water, and assumes the forms of minute globules.

1329 *What causes the visible white appearance of condensed steam?*

The myriads of *minute globules of water* into which the steam is condensed are separately invisible to the naked eye, but each, nevertheless, reflects a minute ray of white light. The multitudes of these reflecting points, therefore, make the space through which they are diffused appear like a cloudy body, more or less white, according to their abundance.

1330 *In what manner is the production of steam in boiling water first manifested?*

When steam begins to be produced, as in the process of making water boil, and the heat overcomes the atmospheric pressure on the surface, small bubbles are formed, adhering slightly to the sides of the vessel.

1331 *In what parts of the boiler will its development be most conspicuous?*

The bubbles are formed most rapidly at those points against which the flame is most strongly directed.

1332 *How much lighter is steam than water?*

About 1700 times; because a quantity of water yields nearly 1700 measures of steam at 212° F.

Fig. 45 represents the comparative volume of water and of steam.

Fig. 45.

1333 *How much steam will a cubic inch of water furnish?*

A cubic inch of water expands into about a *cubic foot of steam* at 212° F., under the ordinary atmospheric pressure.

1334 *Upon what does the power of steam depend?*

On the tendency which water possesses to *expand into vapor* when heated to a certain temperature.

1335 *What is the most important property of steam?*

Its *elasticity* or *pressure.* By virtue of this property, when freed from the limits which confine it, steam will dilate into any space to which it may have access.

1336 *If a quantity of pure steam be confined in a close vessel, in what manner will its pressure be exerted?*

It will exert on every part of the interior of the vessel a certain pressure *directed outwards*, and having a tendency to *burst* the vessel.

1337 *How great a pressure does steam, formed under ordinary circumstances, have to overcome before it can rise from the surface of the water?*

That of *one atmosphere—fifteen pounds* on every *square inch*, or *one ton* on every *square foot*—a force equivalent to the strength of *six hundred horses.*

1338 *What happens when the temperature of steam generated under ordinary pressures is reduced below* 212° *F.?*

It is immediately *condensed into water.*

1339 *As steam sustains and elevates a weight occasioned by the pressure of the atmosphere, of fifteen pounds per square inch, what takes place when a column of steam is immediately condensed?*

The atmospheric weight will *immediately fall* with a force equal to that with which it was raised.

1340 *How can steam be used to advantage for cooking vegetables, etc.?*

In cookery, if steam raised from boiling water be allowed to pass through meat and vegetables, it will be *condensed* upon their surfaces, imparting to them the latent heat which it contained before its condensation, thus cooking them as effectually as if they were immersed in boiling water.

1341 *What do we mean when we speak of high-pressure steam?*

High-pressure steam is merely steam *condensed*, not by withdrawal of heat, but by *pressure*, just as high-pressure air is merely condensed air. To obtain a double, triple, or greater pressure of steam, we must have twice, thrice, or more steam under the same volume.

1342 *Is high-pressure steam, escaping from a boiler heated to* 300° *or more, hotter than low-pressure steam escaping from a boiler at* 212°?

No; for the instant that high-pressure or condensed steam escapes into the air, it immediately *expands* and *becomes low-pressure steam*, and is greatly cooled down by its expansion.

1343 *Does high-pressure steam, acting in a boiler at a high temperature, exert a greater mechanical and chemical power than low-pressure steam?*

It *does;* high-pressure steam acting upon bones, breaks up and dissolves the whole mass, extracting all the glue and fat, when ordinary steam would dissolve nothing.

In the Western States, where large quantities of lard are manufactured, the whole hog is exposed to high-pressure steam, and the carcass reduced in a short time to a fat fluid mass.

1344 *Can high-pressure steam be raised to a very elevated degree of heat?*

It *can;* in some of the methods lately introduced for purifying oils, etc., the temperature of the steam, before its application, is required to be *sufficiently elevated* to enable it to *melt lead.*

1345 *What is the steam-engine?*

The steam-engine is a *mechanical contrivance* by which coal, wood, or other fuel is rendered capable of *executing any kind of labor.*

1346 *What substance furnishes the means of calling the powers of coal into activity?*

Water.

1347 *How much water will two ounces of coal evaporate?*

About a pint.

1348 *How much steam will this produce?*

Two hundred and sixteen gallons.

1349 *How much mechanical force can this steam exert?*

It can raise a weight of thirty-seven tons to the height of one foot.

1350 *What amount of force can a man exert when applying his strength to the best advantage through the help of machinery?*

It has been found by experiment, that a man working on a tread-mill continuously for eight hours, will elevate *one and a half millions of pounds to the height of one foot.*

1351 *With how much coal will a well constructed steam-engine perform the same labor?*

With the expenditure of *a pound and a half.*

1352 *How much coal then would be equivalent to the average power of an able-bodied man during his active life, supposing him to work for twenty years at the rate of eight hours per day?*

The consumption of about *four tons* of coal would evolve in a steam-engine fully as much power.

1353 *The great pyramid of Egypt is five hundred feet high, and weighs twelve thousand seven hundred and sixty millions of pounds. Herodotus states that in constructing it one hundred thousand men were constantly employed for twenty years. With how much coal could all the materials of this pyramid be raised to their present position from the ground?*

With the expenditure of *four hundred and eighty tons* of coal.

PART VI.

VENTILATION AND WARMING, COMBUSTION, RESPIRATION, AND NUTRITION.

CHAPTER I.

WARMING AND VENTILATION.

1354 *What is ventilation?*

Ventilation is the act or operation of causing air to pass through any place, for the purpose of expelling impure air and dissipating noxious vapors.

1355 *What is the theoretical perfection of ventilation?*

To render it impossible for any portion of air to be breathed twice in the same building.

1356 *Upon what principle does the whole process of warming and ventilating buildings depend?*

Upon the expansion and contraction of air, or, in other words, upon the fact that air which has been heated and expanded ascends, and air which has been deprived of heat, or has become contracted, descends.

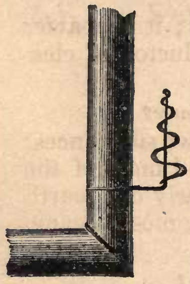


Fig. 46.

1357 *Is there an upward current of air always rising from heated substances?*

There is; air made lighter by heat *ascends through colder strata*, as a cork (put at the bottom of a basin of water) rises to the surface.

1358 *What simple experiment shows the existence of this upward current in an ordinary stove?*

If we attach to the side of a heated stovepipe a wire on which a piece of paper cut in the form of a spiral may be suspended, as is represented in *Fig.* 46, the upward current of hot air will immediately put the paper in motion, and make it revolve rapidly around the wire.

1359 *When a boy makes a fire-balloon, and sets fire to the cotton or sponge (which has been steeped in spirits of wine), why is the balloon inflated?*

Because the *air* of the balloon is *expanded* by the heat of the flame, and fills the balloon to its utmost capacity.

1360 *Why does the balloon rise after it has been inflated by the expanded air?*

Because the same quantity of air is *expanded to three or four times its original volume;* and made so much *lighter*, that even when all the paper, wire, and cotton are added, it is still lighter than common air.

1361 *In what situation is ventilation perfect?*

In the open air, because the breath, as it leaves the body, is warmer and lighter than the surrounding fresh air, and ascending is immediately replaced by an ingress of fresh air ready to be received by the next respiration.

1362 *Why is it desirable to avoid breathing the same air twice?*

Air which has been once respired, is unwholesome, and not suited to supply the wants of the animal system.

1363 *What are the elements of atmospheric air?*

Oxygen and nitrogen mixed together, in the proportion of seventy-nine parts of nitrogen and twenty-one of oxygen.

1364 *What is oxygen?*

A *gas*, colorless, tasteless, and odorless; it is heavier than atmospheric air, and is a non-conductor of electricity.

1365 *Is oxygen a substance existing in great abundance?*

Oxygen is the *most abundant* of all known substances; it constitutes at least one third of the solid mass of the globe, eight-ninths of all water, and nearly one-fourth part of the atmosphere; it also exists in most organic substances.

1366 *Is oxygen ever found in a liquid or solid state?*

No; when pure it is only known in the gaseous state; all efforts to reduce it to a liquid or solid condition by cold or pressure have completely failed.

1367 *Of what use is oxygen in the atmosphere?*

It sustains *animal life* and *supports combustion.*

1368 *If an animal were immersed in oxygen gas, would it continue to live for a time?*

It *would;* at the same time animal life could not be sustained for any great length of time in an atmosphere of pure oxygen.

1369 *What is meant when it is said that oxygen "sustains life?"*

It means this: if a person could not inhale oxygen, he would *die.*

1370 *What good does this inspiration of oxygen do?*

1. It gives vitality to the blood; and
2. It is the *cause* of animal heat.

1371 *What is nitrogen?*

An *invisible gas* existing largely in atmospheric air, and in most animal and vegetable substances.

1372 *What are its principal characteristics?*

1. It is *not combustible;*
2. It does *not support animal life;* and
3. It is the *principal ingredient* in the composition of *atmospheric air.*

1373 *What proportion of the air we breathe is composed of nitrogen?*

About *four-fifths of the air is nitrogen;* the other one-fifth is *oxygen.*

1374 *Why is there so much nitrogen in the air?*

The uses of nitrogen are in a great measure unknown. It has been supposed to act as a *diluent to the oxygen,* but it most probably serves some useful purpose in the economy of animals and vegetables, the exact nature of which has not been discovered.

1375 *What would be the effect if the proportion of oxygen in the atmosphere were increased?*

The *inflammability* of most substances would be *increased,* fires would burn out very quickly, and the functions of life would be called into such rapid action as to soon exhaust the powers of the system.

1376 *Are the two gases, oxygen and nitrogen, existing in the atmosphere, chemically combined, or merely intermingled?*

They are *merely mixed*, and not combined with each other.

1377 *Does the atmosphere always contain any other ingredients besides oxygen and nitrogen?*

There is always in the air, at all places, *carbonic acid gas*, in variable proportions, and watery vapor, besides the odoriferous matter of flowers and other volatile substances.

1378 *What is carbonic acid gas?*

A gas formed by the union of carbon and oxygen; it used to be called *fixed air*. Its chemical composition is one atom of carbon united to two of oxygen.

1379 *Is the air collected on the tops of high mountains, over marshes in hospitals, and over deserts, the same in character and composition?*

It is *not found to vary*, but is the *same* in all regions of the earth and at all altitudes.

1380 *Are the component parts of air, oxygen, nitrogen, carbonic acid, and watery vapors, of different specific gravities, or do they all differ in weight?*

They are all *different*, carbonic acid gas being the heaviest.

1381 *Then, as we have before stated that they are merely mixed, and not combined, why do they not arrange themselves in the order of their densities, and float one upon the other, as oil and water do when mingled?*

Because of a wonderful principle or law of nature, that when two gases of different weights or specific gravities are mixed together, they *cannot remain separate, as fluids of different densities do*, but diffuse themselves uniformly throughout the whole space which both occupy.

1382 *Carbonic acid is twenty times heavier than hydrogen gas; if we fill the lower part of a tall jar with carbonic acid, and the upper part with hydrogen, will the two gases mix?*

After a few hours the two gases will be found *equally* *mingled*, as much carbonic acid being at the top of the jar as at the bottom.

1383 *Does this law appear to be opposed to the principles of the law of gravitation?*

It appears to be *opposed to it;* the only exception we are acquainted with in the natural world.

1384 *How much carbonic acid is estimated to exist in the atmosphere?*

About *one part* in *two thousand, by volume.*

1385 *If this were all collected in one layer over the surface of the earth, how great a thickness would this layer or stratum have?*

About *thirteen feet.*

1386 *Can we breathe carbonic acid?*

No; the animal immersed in it *dies instantly.*

1387 *If, then, this singular law of the diffusion of gases did not prevail, would the surface of the earth be habitable?*

It would *not;* carbonic gas would fill up all the valleys and lower levels, separating every hill and elevation by an invisible ocean of poisonous gas, as impassable as the barrier between the dead and the living.

1388 *Is it owing to this law that we are enabled to enjoy and perceive at a distance the odor of a flower-garden, or the perfume which has been opened in an apartment?*

It is by this law that a vapor, arising by its own elasticity from a volatile substance, is *caused to extend its influence* and *mingle* with the surrounding atmosphere, until its effects become so enfeebled by dilution as to be imperceptible to the senses.

1389 *If the oxygen and nitrogen of which our atmosphere is composed were combined together, instead of being merely mingled, what would the compound be?*

A most *deadly poison.*

1390 *What gas is generated by a lighted candle or lamp?*

Carbonic acid gas—formed by the union of the *carbon* of the *oil* or *tallow* with the *oxygen of the air.*

1391 *Under what circumstances does carbon most readily unite with oxygen?*

1. When its temperature is raised: thus, if carbon be *red hot*, oxygen will most readily unite with it;

2. Carbon in the *blood* unites readily with oxygen during *respiration;* and

3. Carbonic acid is formed in large quantities during the chemical changes which we call *fermentation.*

1392 *Is carbonic acid in any degree wholesome?*

No; it is fatal to animal life, and (whenever it is inhaled) acts like a narcotic* poison, producing drowsiness, which sometimes ends in death.

1393 *When persons commit suicide by building a charcoal fire in a closed room, what occasions their death?*

The *inhalation of carbonic acid*, which is generated by the combustion of the charcoal.

1394 *How can any one know if a place be infested with carbonic acid gas?*

If a pit or well contain carbonic acid, a lighted candle (let down into it) will be instantly extinguished. The rule, therefore, is this: where a *candle will burn, a man can live;* but *what will extinguish a candle*, will also *destroy life.*

1395 *Why does a crowded room produce headache?*

Because we breathe air vitiated by the *crowd.*

1396 *Why is the air of a room vitiated by a crowd?*

Because it is deprived of its due proportion of oxygen, and *loaded* with carbonic acid.

1397 *How is the air of a room affected thus by a crowd?*

The elements of the air inhaled are separated in the lungs; the oxygen, incorporated in the blood, forms carbonic acid; and the carbonic acid (together with the nitrogen) is thrown back again by the breath into the room.

1398 *Is all the nitrogen rejected by the lungs?*

Yes; all the nitrogen of the air is always *expired.*

1399 *How much oxygen does a full-grown person consume per hour?*

It is calculated that an adult of average size absorbs

* A narcotic is a substance which, when used as a medicine, relieves pain and produces sleep, but in poisonous doses produces death. Opium, laudanum, tobacco, etc., are narcotics.

about *a cubic foot of oxygen per hour* by respiration, and consequently renders five cubic feet of air unfit for breathing, since every five cubic feet of air contain one cubic foot of oxygen. It is also calculated that two wax or sperm candles absorb as much oxygen as an adult.

1400 *To keep the air of a room pure, how much fresh air should be allowed to pass in per hour?*

Five cubic feet for each person, and *two and a half cubic feet for each candle*, should be allowed to pass in, and an equal quantity to pass out.

1401 *Why do persons in a crowded church feel drowsy?*

1. Because the crowded congregation inhale a large portion of the oxygen of the air, which alone can sustain vitality and healthy action; and

2. The air of the church is *impregnated with carbonic acid gas*, which (being a strong narcotic) produces drowsiness in those who inhale it.

1402 *Why do persons who are much in the open air enjoy the best health?*

Because the air they inhale is much more pure than the air of close and confined rooms.

1403 *How does vegetation (trees and flowers) serve to purify the air?*

1. Because trees and flowers absorb the carbonic acid generated by the lungs of animals, putrid substances, and other obnoxious exhalations; and

2. Trees and flowers *restore* to the air the oxygen which man and other animals inhale.

1404 *Why is the air of cities generally less pure than the air of the open country?*

1. Because there are more *inhabitants* to vitiate the air;

2. The *sewers*, *drains*, *bins*, and *filth* of a *city* very greatly vitiate the air;

3. The streets and alleys prevent a free circulation; and

4. There are fewer trees to absorb the excess of carbonic acid gas, and restore the *equilibrium*.

1405 *Why are persons who live in close rooms and crowded cities generally sickly?*

Because the air they breathe is not pure, but is (in the first place) *defective in oxygen*, and (in the second) is impregnated with *carbonic acid gas.*

1406 *Where does the carbonic acid of close rooms and cities come from?*

From the lungs of the inhabitants, the sewers, drains, and other like places, in which organic substances are undergoing *decomposition.*

1407 *What becomes of the carbonic acid generated in crowded cities?*

It is gradually diffused through the air, absorbed by vegetation and by water, and wafted by the winds to different localities.

1408 *Does not this constant diffusion of carbonic acid affect the purity of the whole air?*

No; because it is wafted by the wind from place to place, and *absorbed* in its passage by the *vegetable world.*

1409 *What is choke damp?*

Carbonic acid gas accumulated at the bottom of wells and pits, which renders them noxious, and often fatal to life. It is called *choke* damp, because it *chokes* (or suffocates) *every animal* that attempts to *inhale it.*

It suffocates without getting into the *lungs*, by closing the glottis *spasmodically.*

1410 *Why is not this carbonic acid taken up by the air and diffused, as it is in cities?*

Because (being heavier than common air) it cannot readily rise from the well or pit; and no wind can get to it to blow it away.

By the chemical law of diffusion, a portion of the carbonic acid which accumulates at the bottom of wells and pits, is removed; but in many cases this abstraction is more than counterbalanced by an increased supply.

1411 *How much carbon in the form of carbonic acid passes through the lungs of a healthy person every twenty-four hours?*

The quantity would be very accurately represented by a *mass of charcoal* of the weight of *fifteen ounces.*

The volume of carbon in the atmosphere, although it forms but one per cent. of the carbonic acid existing in it, exceeds in amount all the carbon that is stored in the earth in the form of coal, or spread over its surface in the form of animals or vegetables.

1412 *What are the chief sources of carbonic acid?*

Combustion, *respiration* of men and animals, the *decomposition of organic substances*, and the *exhalations of volcanoes.* Carbonic acid also exists in large quantities in the atmosphere, in most waters, and combined with minerals in a solid state, as in marble, which consists of lime united to carbonic acid.

1413 *From which of these sources is carbonic acid most likely to accumulate to a noxious extent?*

From the *fermentation* and *putrefaction* of decaying vegetable and animal matters.

1414 *How can this accumulation of carbonic acid be prevented?*

By throwing quicklime *into places* where such fermentation and putrefaction are going on.

1415 *How will quicklime prevent the accumulation of carbonic acid?*

Quicklime will absorb the *carbonic acid*, and produce a combination called "carbonate of lime."

1416 *Does not heavy rain, as well as quicklime, prevent the accumulation of carbonic acid?*

Yes; an abundant supply of water will prevent the accumulation of carbonic acid, by *dissolving* it.

1417 *Is the external air always in motion?*

Some portion of the atmosphere is always in motion. Currents of warm air ascending, and currents of cold air descending.

1418 *Is the air of our rooms always in motion?*

Yes; there are always *two currents of air* in the room we occupy; one of *hot* air flowing *out* of the room, and another of *cold* air flowing *into* the room.

1419 *How do you know that there are these two currents of air in every occupied room?*

If I hold a lighted candle near the crevice at the *top of the door*, the flame will be blown *outwards* (towards the *hall*); but if I hold the candle at the *bottom of the door*, the flame will be blown *inwards* (into the *room*).

This is not the case if a *fire* be in the room. When a fire is lighted, an inward current is drawn through *all* the crevices.

1420 *Why would the flame be blown outwards (towards the hall) if a candle be held at the top of the door?*

Because the air of the room being heated, and consequently rarified, *ascends*, and (floating about the upper part of the room) some of it escapes *through the crevice* at the *top of the door*, producing a current of air *outwards* (into the *hall*).

1421 *Why would the flame be blown inwards (into the room) if the candle be held at the bottom of the door?*

Because a partial *vacuum* is made at the *bottom of the room*, as soon as the warm air of the room has ascended to the ceiling or made its escape from the room; and the cold air from the hall *rushes under the door* to supply the void.

1422 *What is meant by a partial vacuum being made at the bottom of the room?*

It here signifies a place *from which the air has been taken;* and a "partial vacuum" means a place from which a *part* of the air has been taken away. Thus, when the air near the floor *ascends* to the ceiling, a partial vacuum is made near the *floor*.

1423 *And how is the vacuum filled up again?*

It is filled up by *colder* air, which rushes (under the *door*, and through the *window* crevices) into the room.

1424 *Give me an illustration.*

If I dip a pail into a pond and fill it with water, a hole (or vacuum) is made in the pond as *big as the pail;* but the moment I *draw the pail out*, the hole is *filled up* by the water around.

1425 *Show how this illustration applies.*

The heated air which ascends from the bottom of a room is as much taken away as the water in the pail, and (as the void was instantly supplied by *other water in the pond*) *so* the *void of air is supplied* by the air around.

1426 *Why is a room (even without a fire) generally warmer than the open air?*

Because the air in a room is *not subject to much change*, and soon partakes of the same temperature as our bodies, when it no longer feels cold.

1427 *Why do we generally feel colder out-of-doors than in-doors?*

Because the air (which surrounds us) is *always changing;* and as fast as *one* portion of air has become warmer by contact with our body, *another colder portion* surrounds us, to absorb more heat.

1428 *Why is there always a draught through the window crevices?*

Because the external air (being colder than the air of the room we occupy) rushes through the window crevices, *to supply the deficiency* caused by the escape of warm air up the chimney, etc.

1429 *Why, when we kindle a fire in a stove or grate, does the smoke ascend the chimney?*

When a fire is lighted to warm a room, the smoke and other gaseous products of combustion, being lighter than the air of the room, ascend, and soon fill the chimney with a column of air lighter, bulk for bulk, than a column of atmospheric air.

1430 *Is the column of light air in the chimney pressed up by a column of equal size on the exterior of the chimney?*

It is.

1431 *What, then, is the draught of a chimney?*

It is the rate or speed with which the column of cold air outside the chimney pushes up the column of warm air inside the chimney, and this draught will be strong and effective just in the same proportion as the column of air in the chimney is kept warm.

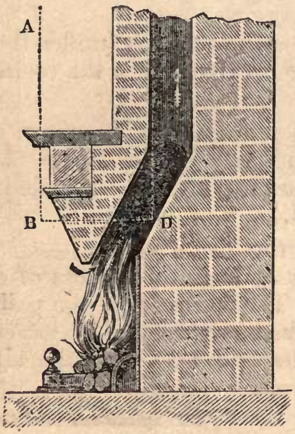


Fig. 47

Fig. 47 represents a section of a grate and chimney. C D represents the light and warm column of air within the chimney, and A B the cold and heavy column of air outside the chimney. The column A B being cold and heavy presses down, the column C D being light and warm rushes up, and the greater the difference between the weight of these two columns, the greater will be the draught.

1432 *How do chimneys quicken the ascent of hot air?*

By keeping a long column of it together. A column of two feet high rises, or is pressed up, with twice as much force as a column of one foot, and so in proportion for all other lengths—just as two or more corks, strung together and immersed in water, tend upwards with proportionably more force than a single cork.

In a chimney where one foot in height of the column of hot air is one ounce lighter than the same bulk of external cold air, if the chimney be one hundred feet high, the air or smoke in it is propelled upwards with a force of one hundred ounces.

1433 *To what is the draught of a chimney in all cases proportioned to?*

With sufficient fire, to the length of the chimney.

1434 *Why are the chimneys of large manufactories generally very high?*

A long chimney causes a current of air to pass through a fire very rapidly, and at the same time very uniformly. On these accounts, for the fires of steam-engines, etc., long chimneys are preferred.

1435 *When the temperature of the air in a room and of the air outside are the same, will there be any draught up the chimney?*

There will be no draught.

1436 *When there is no fire in stove or grate, and the air of a room is warmer than the air outside, will there be a circulation up and down the chimney?*

In such cases there will generally be two currents, up and down the chimney, especially if the doors and windows of the room be tight. The warm air of the room will ascend through the chimney, and the cold air descend by the side of it, two currents readily circulating through one tube. The direction of the arrows, in *Fig.* 48, will show

Fig. 48.

the lines of the current, descending the chimney and circulating round the apartment.

1437 *Why does an apartment often smell disagreeably of soot in summer-time?*

Because the air in the *chimney* (being *colder* than the air in the *apartment*) *descends into the room*, and leaves a disagreeable smell of soot behind.

1438 *How ought chimneys to be constructed?*

A chimney should be constructed in such a way that the flue or passage will gradually contract from the bottom to the top, being widest at the bottom, and the smallest at the top.

1439 *Why is it expedient to construct a chimney in this manner?*

At the base of the chimney, the hot column of air fills the entire passage; but as the hot air ascends it gradually cools and contracts, occupying less space. If, therefore, the chimney were of the same size all the way up, the tendency would be, that the cold external air would rush down to fill up the space left by the contraction of the hot column of air. This action would still further cool the hot air of the chimney and diminish the draught.

1440 *Why will a long chimney smoke, unless the fire be pretty fierce?*

Because the heat of the fire will not be sufficient to *rarefy all the air in the chimney.*

1441 *Why will the chimney smoke, unless the fire be fierce enough to heat all the air in the chimney-flue?*

Because the *cold air* (condensed in the upper part of the flue) *will sink from its own weight;* and sweep the ascending smoke *back* into the room.

1442 *What is the use of a cowl upon a chimney-pot?*

It acts as a *screen*, to prevent the wind from blowing into the chimney.

1443 *What harm would the wind do if it were to blow into a chimney?*

1. It would prevent the smoke from getting out; and

2. The *cold air* (introduced into the chimney by the

wind) *would fall down the flue,* and drive the smoke with it *into the room.*

1444 *Why do some chimneys smoke?*

Because fresh air is not admitted into a room *as fast as it is consumed by the fire;* in consequence of which a current of air *rushes down the chimney to supply the deficiency,* driving the smoke along with it.

1445 *Why do blowers, when placed before a grate, tend to kindle the fire?*

A blower is a sheet of iron that stops up the space above the grate bars, and prevents any air from entering the chimney except that which passes through the fuel and produces combustion. This soon causes the column of air in the chimney to become heated, and a draught of considerable force is speedily produced through the fire. The increase of draught increases the intensity of the fire.

1446 *Which is the hottest part of a room?*

The upper part, near the ceiling. The warm air being the lightest seeks the highest position.

1447 *Which is the coolest part of a room?*

The lowest part, near the floor. Cold air being dense and heavy seeks the lowest position.

1448 *By which means is a room better ventilated, by opening the upper or the lower sash?*

A room is better *ventilated* by opening the *upper sash;* because the hot vitiated air (which always ascends towards the ceiling) *can escape more easily.*

1449 *What temperature is most proper for keeping an apartment in a healthy and pleasant condition during the cold season?*

From 65° to 70° F., with a *free ventilation.*

1450 *How are houses and other buildings heated with hot air?*

The fire is kindled in a furnace which is erected in the cellar. This fire heats the air in contact with it in the air-chamber, as it is called, and as heated air *always ascends,* it is forced up into the different apartments of the building.

1451 *Which would prove the warmest upon a bed—a blanket, or an oiled silk, or India-rubber air-tight covering?*

The *air-tight* covering.

1452 *Why do we not use oiled silk or India-rubber bed coverings in the winter?*

Because they *prevent ventilation*, and, by shutting in the insensible perspiration, soon produce *dampness*.

1453 *What is smoke?*

Small particles of carbon separated by combustion from the fuel, but not *consumed*.

1454 *Is there a circulation of the air through the bed coverings at night?*

Yes; from every part of the bed-clothes immediately over the person there is a *constant outward oozing* of warm air, and an oozing inwards of cold air in lower situations around.

1455 *In what two ways is heat communicated to apartments by fires kept in them?*

By *radiation* and *immediate contact*.

The first portion passes through the air in diverging lines with great velocity. The second penetrates slowly through the substance of the densest bodies. To enjoy the full effect of radiated heat, we must be in the presence or sight of the radiating object. To receive conducted heat, we must be in contact, either directly or through some intervening medium, with the body that imparts it.

1456 *Does a person who sits by a fire in the open air receive any heat by conduction?*

Very *little;* for the air which surrounds the fire having nothing to confine it, *ascends by its diminished specific gravity* as fast as it is warmed, and its place is immediately supplied by strata of cold air from beneath.

1457 *Will a person sitting beside a fire in the open air be exposed, upon the side of his body removed from the fire, to additional cold?*

He *will*, because cold currents *rush in from every side* towards the fire.

1458 *Why are open fireplaces ill adapted for the economical heating of apartments?*

In an open fireplace the air flows *from* the room *to* the fire, becomes heated, and passes off directly into the chimney, without having an opportunity of parting with its heat for any useful purpose. In addition to this, a quantity of the air of the room, which has been warmed by radiation, is uselessly carried away by the draught.

1459 *What are the advantages of a stove over an open fireplace?*

1. Being detached from the walls of the room, the greater part of the heat produced by combustion is *saved.* The radiated heat being thrown into the walls of the stove, they become hot, and in turn *radiate heat on all sides* to the room. The conducted heat is also received by successive portions of the air of the room, which pass in contact with the stove;

2. The air being made to pass *through the fuel*, a small supply is sufficient to keep up the combustion, so that little need be taken out of the room; and

3. The smoke, in passing off by a pipe, parts with the *greater part of its heat* before it leaves the room.

1460 *What are the disadvantages of stoves?*

Houses containing them are generally *ill ventilated.* The air coming in contact with the hot metal surfaces is rendered impure, which impurity is increased by the burning of the dust and other substances which settle upon the stove. The air is, in most cases, kept so dry as to render it oppressive.

1461 *Upon what principle are the common hot-air furnaces for warming houses constructed?*

A *stove*, having *large radiating surfaces*, is inclosed in a chamber (generally of masonry). This chamber is generally built with double walls, that it may be a better non-conductor of heat. A *current of air* from without is brought by a pipe or box, and delivered *under the stove.* A part of this air is admitted to supply the combustion; the rest passes upwards in the cavity between the hot stove and the walls of the brick chamber, and, after becoming thoroughly heated, is conducted through passages in which its lightness causes it to ascend, and be delivered in any apartment of the house.

1462 *In the construction and arrangement of a furnace for warming, what two points are of special importance, so far as regards the economy of fuel?*

1. The *perfect combustion* of the fuel; and
2. The best possible *transmission* of all the heat formed, into the air that is to pass into the rooms of the house.

1463 *How is the first of these requisites obtained?*

By having a *good draught* and a fire-box which is *broad* and *shallow*, so that the coal shall form a thin stratum; by which arrangement the carbonic acid gas will be freely formed, and pass off without a previous production of an imperfectly burnt product.

1464 *How is the second of these requisites attained?*

By providing a *great quantity of surface* in the form of pipes, drums, or cylinders, through which the smoke and hot gases must pass on their way to the chimney, and to which their heat will be imparted, to be in turn delivered to the cold and pure air of the rooms of the house.

CHAPTER II.

COMBUSTION.

1465 *What is combustion?*

Every species of combustion with which we are familiarly acquainted is the rapid *chemical union* of the *oxygen* of the air with a combustible body, attended with the evolution of *light* and *heat*.

1466 *How may combustion, as we ordinarily see it, be regarded?*

It may be regarded as simply a *process of oxidation*.

1467 *What do we mean by the term oxidation?*

The combination of some substance with oxygen,—or the act of combining with oxygen.

1468 *Is there not always an increase in weight during the combustion of inflammable materials, rather than a loss?*

The products of combustion always *exceed the weight* of the original substance burned, by an amount equal to the weight of the oxygen gas absorbed during the combustion.

1469 *What becomes of the oxidized products of combustion?*

They for the most part *combine with oxygen* to form *gases* and *vapors*. We apply to these products the general term *smoke*.

1470 *What is an essential requisite to every process of combustion?*

That there should be a *free supply of air*, and that the products of combustion, or the *smoke*, should be *conducted off*.

1471 *Why, when we burn a candle or a piece of wood in the air, does there always seem to be a loss of matter?*

Because the results of combustion in these cases are either *gases* or *vapors*, the existence of which, not being apparent to common observation, requires to be made known by experiment.

Until nearly the close of the last century it was generally believed and taught, that when a body was burned, something went out of it,—that it lost weight. Lavoisier, a celebrated French chemist, overthrew this doctrine by burning a substance in connexion with an arrangement whereby all the results or products of the combustion were saved. These on being weighed showed a gain rather than a loss, the amount being equal to the quantity of oxygen which had been absorbed from the air during the process of combustion, by the burning substance itself.

1472 *How is heat evolved by combustion?*

By chemical action. As latent heat is liberated, when water is poured upon lime, by chemical action, so latent heat is liberated in *combustion* by chemical action also.

1473 *What chemical action takes place in combustion?*

The elements of the fuel combine with the oxygen of the air.

1474 *What is the temperature required to induce the combination of oxygen with any substance called?*

The *burning point.*

1475 *Is this point different for different substances?*

It *is:* thus phosphorus will combine slowly at 77° F., but does not enter into rapid combustion until the temperature is raised to 104° F. Charcoal burns slowly below a red heat.

1476 *Is the quantity of heat given out, when a body combines slowly with oxygen, the same as when it combines rapidly with it, the relative quantities of the combining bodies remaining the same in both cases?*

The total quantity of heat given out is the *same*, whether the combustion takes place *slowly* or *quickly;* but in the case of slow combustion, the heat is much less intense, and often becomes insensible, because during the long time occupied in combination the greater part is carried away by conduction.

1477 *Is the quantity of light given out the same, whether the combustion be rapid or slow?*

No: the quantity of light given out during the combination of oxygen with a given quantity of a combustible body *varies greatly*, according to the rapidity of the combustion.

1478 *What is rust?*

The *oxidation* of iron in moist air.

1479 *When iron rusts in the air is heat given out?*

Certainly; but the process of rusting takes place so slowly that the amount of heat given out at any one time is imperceptible to our senses.

1480 *What is flame?*

Burning *gas* or *vapor.*

1481 *What is fire?*

Heat and *light* produced by the combustion of inflammable *substances.*

1482 *What does the brightness or illuminating power of flame depend on?*

It depends on the *degree of heat* in part, but mainly on the presence or absence of solid particles in the flame, which may act as radiating points.

1483 *Are there solid particles in every illuminating flame?*

There *are*; and if we present a cold surface to the flame, they become deposited on it in the form of *soot.*

1484 *When we say a lamp smokes, what do we mean?*

That the *solid parts* of the flame are passing off in an unconsumed state.

1485 *When the flame burns properly, why does the smoke cease to be emitted?*

Because the solid particles of carbon constituting the smoke are *burned up*, or are completely united with oxygen, forming an invisible gas—carbonic acid.

1486 *From what source is the carbon, constituting the illuminating particles in the one case and the soot in the other, derived?*

It was originally a part of the *burning* or *combustible body.*

1487 *When will a flame smoke?*

When the supply of oxygen received from the air is *insufficient to consume all the carbon* which the heat separates from the combustible body in the form of soot.

1488 *What benefit arises from surrounding a flame with a glass cylinder or chimney open at the bottom and top?*

When a flame burns without a chimney, the hot air radiates in *all directions*; but when it is surrounded by a chimney, the hot air is confined within the walls of the cylinder: consequently, the hot air will issue rapidly from the top of the chimney, and cold air will enter equally fast at the bottom to replace it. In this way a constant current of fresh air is kept up through the centre of the flame, causing a more perfect combustion, and a brighter and stronger flame.

1489 *Why in solar and astral lamps do we use a hollow or circular wick?*

In order that a *current of air* may rush up through the interior surface of the flame as well as along the exterior.

1490 *What is fuel?*

Any substance which serves as *aliment* or *food* for *fire.* In ordinary language we mean by fuel the peculiar substance of plants, or the products resulting from their decomposition, designated under the various names of wood, peat, and coal.

1491 *What are the constituents of wood?*

Carbon, *hydrogen*, and *oxygen*, combined together, make up the chief part of its bulk; all wood also contains water.

1492 *What is hydrogen?*

It is an *inflammable gas*, one of the elements of which water is composed. The gas used in our streets is in great part hydrogen. Hydrogen, when pure, has neither taste nor odor.

1493 *What are the peculiar characteristics of hydrogen gas?*

1. It is the lightest of all known substances;
2. It will burn immediately on being ignited; and
3. A lighted candle (immersed in this gas) will be instantly extinguished.

1494 *What is carbon?*

A *solid elementary substance*, generally of a dark or black color, well known under the forms of *charcoal*, *lampblack*, *coke*, etc.

1495 *What is charcoal?*

Wood which has been exposed to *heat* until it has been deprived of all its gases and volatile parts.

1496 *Can all animal and vegetable substances, by partial burning, be converted into coal?*

They *can*.

1497 *In the charring of animal and vegetable substances, do we generate charcoal, or did it exist there before?*

The carbon or coal existed there *previously*, though in chemical combination with other bodies, which are principally driven off by heat, as is apparent from the fact that a charred body weighs much less than the original substance; animal and vegetable substances consist, therefore, in part of coal.

1498 *What is soot?*

Coal in a state of *minute division*, which is deposited from the flame of bituminous or pit-coal, wood, oil, resin, etc., when, during the combustion of these substances, there is an insufficient supply of air.

1499 *How is charcoal prepared?*

By *charring wood* in mounds or pits, covered with turf or soil in such a way as to exclude in a great degree the admission of air, and thus prevent complete combustion.

1500 *What is mineral or hard coal?*

Coal is the product of a vast accumulation of vegetable matter, deposited during a remote geological period in beds or layers in the earth, and which, by the action of pressure, heat, and other causes, has become consolidated and hardened into its present form.

1501 *How does the coal occur in the earth?*

In *strata* or layers, varying from a few inches to several feet in thickness, inclosed between other strata of limestone, clay, or iron ore.

1502 *In what manner is it supposed that this great accumulation of vegetable material took place?*

The vegetable matter of which coal is composed is supposed, by some, to have grown in *immense swamps* or *marshes.* By others, the vegetable matter is supposed to have been *swept down by rivers*, and deposited at their mouths or estuaries in immense beds.

1503 *Are such accumulations of vegetable matter, through the agency of rivers, going on at the present day?*

At the present time the *Red River of Texas* is absolutely *choked up* with a raft composed of *trunks of trees* and other *vegetable matter*, many miles in extent, and of unknown thickness. Other rivers of the Southwestern United States bring down vegetable materials annually, sufficient for the production of vast beds of coal.

1504 *How do we know that coal is all vegetable matter?*

Because in every coal mine we find the *leaves*, *trunks*, and *fruits of trees* in immense numbers, many of them in a most *perfect state of preservation;* so much so, that the botany of the coal period can be studied with nearly as great ease and facility as the botany of any given section of the present surface of the earth.

1505 *What occasions the difference between bituminous and anthracite coal?*

Bituminous coal contains a large amount of *bitumen* and other *pitchy volatile* substances which readily ignite and burn with smoke and flame. In anthracite coal these substances have been driven out; it is therefore a purer variety of carbon, and burns without smoke or flame.

1506 *Are the deposits of coal of very great extent?*

They are; mineral coal exists in *all the great divisions of the earth.* The largest deposits of coal, however, occur, in the United States, in Pennsylvania and the Valley of the Mississippi.

1507 *Why will not stones do for fuel as well as coal?*

Because they contain no hydrogen, *and little* or *no* carbon.

1508 *Of what are oil, tallow, and wax composed?*

Principally of carbon and hydrogen gas. The *solid* part is carbon, the *volatile* part is hydrogen gas.

1509 *At what period of the year does wood contain the greatest amount of water?*

In the *spring* and *summer*, when the sap flows freely and the influence of vegetation is the greatest.

1510 *Why is wood generally cut in the winter season?*

Because at that season there is but *little sap* in the tissues, and the wood is drier than at any other period.

1511 *Why is it difficult to inflame coal or hard wood with the blaze of a match?*

Coal and *hard wood* on account of their density are good conductors, and carry off the heat of the kindling substance, so as to extinguish it, before they themselves become raised to the temperature necessary for their combustion.

1512 *Why is it easy to ignite light fuel with a small blaze?*

Light fuel being a slow conductor of heat *kindles* *easily*, and, from the admixture of atmospheric air in its pores and crevices, burns out rapidly, producing a comparatively temporary, though often strong heat.

1513 *In recently cut wood, what proportion of its weight is water?*

From *one-fifth* to *one-half.*

1514 *After wood has been dried in the air for ten or twelve months, how much water does it usually contain?*

From *twenty to twenty-five per cent.*

1515 *Why do we call some woods hard, and others soft?*

This distinction is grounded upon the *facility* with which they are *worked*, and upon their power of *producing heat.* Hard woods, as the oak, beech, walnut, elm, and alder, contain in the same bulk more solid fibre, and their vessels are narrower and more closely packed than those of the softer kinds, such as pine, larch, chestnut, etc.

1516 *How many pounds avoirdupois are there in a cord of dry, hard wood?*

From *forty-four hundred pounds* in a cord of dry hickory, to *twenty-six hundred* in a cord of dry, soft maple.

1517 *What is the most valuable wood for fuel?*

The varieties of *hickory;* after that, in order, the *oak*, the *apple-tree*, the *white-ash*, the *dog-wood*, and the *beech.*

1518 *What woods give out the least heat in burning?*

The *white-pine*, *white-birch*, and *poplar.*

1519 *Why is it unprofitable to burn green wood or wet coal?*

It is a well-known law of heat that the *evaporation of liquids*, or their conversion into steam, consumes or renders latent a great amount of caloric. When green wood or wet coal are added to the fire, they abstract from it by degrees a sufficient amount of heat to convert their own sap or moisture into steam before they are capable of being burnt. As long as any considerable part of this fluid remains unevaporated, the combustion goes on slowly, the fire is dull, and the heat feeble.

1520 *Is there any truth in the remark often made "that it is economy to burn green wood because it is more durable, and therefore in the end more cheap?"*

No; it is true that the consumption of green wood is *less rapid* than dry, but to produce a given amount of heat, a far greater amount of fuel must be consumed.

1521 *In ordinary fuel, what three elements enter into the process of combustion?*

Hydrogen gas, *carbon*, and *oxygen* gas; the two former in the fuel, and the latter principally in the air which surrounds the fuel.

1522 *What chemical changes in air and fuel are produced by combustion?*

1. Some of the *oxygen* of the air, combining with the hydrogen of the fuel, forms vapor of *water;* and

2. Some of the *oxygen* of the air, combining with the carbon of the *fuel*, forms carbonic acid gas.

1523 *Why is there more smoke when fresh fuel is added than when the fuel is red hot?*

Because more carbon and volatile matters are separated from the fuel than can be *reduced by combustion;* and the surplus flies off in smoke.

1524 *Why is there so little smoke with a red-hot fire?*

Because the *entire surface* of the coals is in a state of combustion; and, as very little of the escaping carbon remains unconsumed, there is but little smoke.

1525 *When a coal fire is lighted, why are paper and wood laid at the bottom, against the grate?*

That the flame may *ascend* through the fuel to heat it. If the fire were kindled from the *top*, the flame would *not come in contact* with the fuel placed below.

1526 *Why do we cover up a fire with ashes or cinders to preserve it?*

The covering of ashes or cinders protects the fire from the action of the air, and when fuel is deprived of air it ceases to burn.

1527 *Why does a fire burn so fiercely in windy weather?*

Because the air is rapidly changed, and affords plentiful nourishment to the fire.

1528 *Why does a pair of bellows aid in kindling a fire?*

Because it *drives the air* more rapidly *to the fire*, and the plentiful supply of oxygen soon makes the fire burn intensely.

1529 *Why does water extinguish a fire?*

1. Because the water forms a coating over the fuel, which keeps it from the air; and

2. The conversion of water into steam draws off the heat of the burning fuel.

1530 *Why does a blast of air from a pair of bellows often extinguish a red-hot coal of anthracite?*

Because the cold air *absorbs the heat* of the coal so quickly that it extinguishes it.

1531 *Why can you not light a candle or lamp with a match so long as the sulphur on the end of it is burning?*

The chemical reason for this well known fact is, that the *sulphurous acid*, formed by combustion of sulphur in the air, *surrounds the wick*, and *abstracts* the *oxygen* from the air, by passing to a higher state of oxidation; and this heavy vapor hangs about the wick and excludes the air.

1532 *Cannot wood be made to blaze without actual contact with fire?*

Yes; if a piece of wood be held *near* the fire for a little time, it will blaze, even though it does not *touch the fire*.

1533 *Why will wood blaze, even if it does not touch the fire?*

Because the heat of the fire drives out the *inflammable gas* of the wood, which gas is ignited by contact with the red-hot coals.

1534 *What causes the heat of fire?*

The *carbon of fuel* (when heated) combines with the oxygen of the *air*, and produces *carbonic acid gas*. Again, the *hydrogen* of the *fuel* combining with *other portions* of oxygen, condenses *into water;* by which chemical actions *heat is evolved*.

1535 *Whence does the heat of a dunghill arise?*

As the *straw*, etc., of the *dunghill* decays, it *under-*

goes fermentation, which produces *carbonic acid gas;* and heat is evolved through a species of combustion.

1536 *On what does the intensity of fire depend?*

The *intensity* of fire is always in proportion to the *quantity of oxygen* with which it is supplied.

1537 *Why does stirring a dull fire serve to quicken it?*

Because it breaks up the compacted cinders and coals, making a passage for the air into the very *heart* of the fire.

1538 *Why is the flame of a candle extinguished when blown by the breath, and not made more intense, like a fire?*

Because the flame of a candle is confined to a very small wick, from which it is *severed* by the breath, and (being unsupported) *must go out.*

1539 *When a chimney with an open fireplace gets on fire, and burns so as to endanger the house, how may it at once be extinguished?*

By throwing a quantity of *brimstone* or *sulphur* into the fire, and *closing up the fireplace* with a fireboard or screen. The sulphurous acid soon fills the chimney, and taking up all the oxygen from the contained air, extinguishes the fire. Even the fire, after it has extended into the woodwork of the house, may be extinguished by this simple method.

1540 *Fire in a chimney may be also extinguished by closing the top of the flue with a damper: how does this extinguish the fire?*

It *cuts off the draught*, and the carbonic acid generated by the combustion soon puts an end to the fire.

1541 *What is meant by spontaneous combustion?*

Combustion produced without *contact with fire or flame.*

1542 *Give me an example of spontaneous combustion.*

Oiled cotton and rags imbued with any drying oil, when packed in mass in a barrel, take fire, after a time, at ordinary temperatures. Mixed lampblack and linseed-oil cake take fire at ordinary temperatures, if the lampblack is in excess, or a portion of it is dry.

1543 *What is generally the cause of spontaneous combustion?*

The *absorption of oxygen.* Porous bodies, that are at the same time bad conductors of heat, by the absorption of oxygen may become red hot, and finally burst into a flame.

1544 *Is pine charcoal capable of taking fire at an extremely low temperature?*

Porous bodies, like pine charcoal, when perfectly dry, *absorb* oxygen *rapidly* from the air, and take fire at a temperature below 212° Fahrenheit, or the boiling-point of water.

This has been proved by actual experiment, a piece of light pine charcoal taking fire on a surface of sheet iron, heated below the boiling-point of water.

1545 *Why are not all flames equally luminous?*

In all flames, the light is mainly emitted from minute particles of matter, intensely heated, and floating in the burning gas or vapor ; and hence a flame containing few such particles, will emit but a feeble light, even though its temperature is very great.

1546 *Upon what fact does the production of artificial light depend?*

Upon the fact that at certain high temperatures all matter becomes luminous.

1547 *In order that we may profitably use a combustible body for illuminating purposes, what is required of the products of the combustion?*

That they should be volatile, and freely escape from the immediate vicinity of the illuminating centre.

1548 *The product of all the ordinary forms of combustion is a gas—carbonic acid: what would have been the result if the product of every combustion had been a permanent solid?*

The world would have been *buried beneath its own ashes.*

1549 *Why is the flame of an ordinary fire yellow?*

Because the *heat* is *not sufficient* to render the carbon *white* hot. Increase the intensity of combustion, and the color of the burning bodies or the flames rises from red to yellow, and from yellow to white.

1550 *A candle burns when lighted: explain how this is?*

The heat of the lighted wick decomposes the tallow into its elementary *constituents*, *hydrogen* and *carbon.* The hydrogen is first consumed as a gas by itself with an almost imperceptible light, but with a powerful evolution of heat; this causes the carbon, simultaneously eliminated, to become incandescent and consequently luminous.

1551 *As more carbon is successively eliminated, what becomes of it?*

The moment the incandescent floating carbon comes to the edge of the flame, it finds the oxygen of the air, *unites with it*, and becomes *converted into the invisible gas, carbonic acid*, while its place is occupied immediately by another portion of solid carbon.

1552 *What if there is not sufficient oxygen to consume the carbon?*

It then *passes off as soot*, and we say the candle *smokes.*

1553 *Where is the tallow or wax of a candle decomposed?*

In the wick. The melted tallow or wax *rises up the wick* by capillary attraction, and is rapidly decomposed by the heat of the flame.

1554 *Of what three parts does the flame of every lamp or candle consist?*

The flame of every lamp or candle consists of *three cones.* The innermost cone (*a*, *Fig.* 49) consists of gaseous matter produced by the decomposition of the tallow; this is at a temperature below redness. Around it is the luminous cone (*b*), consisting of burning hydrogen, in which the particles of carbon float at a white heat; and on the very outside (*c*), a thin, hardly-perceptible veil in which carbon is burning. The veil is of a blue color, most plainly seen at the bottom of the flame.

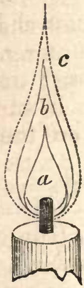


Fig. 49.

1555 *Which is the hottest part of the flame?*

The *pale blue flame;* this marks the point where the combination of the oxygen, supplied from without, with the combustible matter evolved from the interior takes place.

1556 *Why does the flame of a candle point upwards?*

Because it heats the surrounding air, which (being hot) *rapidly ascends*, driving the flame upwards at the same time.

1557 *Why does the hand, held above a candle, suffer more from heat than when it is placed below the flame, or on one side of it?*

Because the *hot gases and air* (in their ascent) come in contact with the hand placed *above* the flame; but when the hand is placed *below* the flame, or on *one side*, it only feels heat from *radiation.*

1558 *Why is not the wick of a candle consumed?*

The wick, although it is blackened by the heat, is prevented from consuming, merely because it is *surrounded by inflammable vapor*, so that the oxygen of the atmosphere has no access to it.

1559 *Why do all closed lamps require a small hole in the top?*

To admit the *air;* otherwise the pressure of the atmosphere will prevent the oil from ascending the wick; if the hole be obstructed, the oil will sometimes *overflow* from the expansion of the confined air.

1560 *Why do we use ground-glass globes for lamp shades?*

To *relieve the eye* from the glare of light. Ground-glass shades have the effect to *disperse the rays* by the numerous reflections and refractions which they occasion; until at length the light issues from all parts of their surface, and it appears as though the glass itself were the luminous body.

CHAPTER III.

RESPIRATION AND NUTRITION.

1561 *What is respiration?*

The act of *inhaling air* into the lungs, and again *expelling it.*

1562 *What is the object of drawing air into the lungs and again expelling it?*

To *oxidize* the carbon and hydrogen of the blood.

1563 *We receive into the lungs oxygen through the medium of the atmosphere, mingled with nitrogen: what do we expel from the lungs?*

The *nitrogen* returns unaltered; the *oxygen* unites with the *carbon* of the blood to form a gas—*carbonic acid*, and with *hydrogen* to form the *vapor of water.*

1564 *Are not these the same products of every ordinary form of combustion?*

They *are;* therefore *respiration* or *breathing* is but a form of *combustion.*

1565 *It is estimated that a man receives into his system about eight hundred pounds of oxygen from the atmosphere in a year, but his weight at the end of the year has increased but little, or not at all: what becomes of all this oxygen?*

No part of it remains in the body, but is *given out again*, combined with carbon and hydrogen.

1566 *How much carbon passes out of the system of an adult man by the agency of respiration daily?*

About *fifteen ounces.*

1567 *How is this great abstraction of material from the body made up?*

By the *food* which we eat.

1568 *What are the lungs?*

Lungs are made up of *bloodvessels* imbedded in a fleshy substance which we denominate *cellular tissue*, and expanded over the walls of a series of chambers or cavities.

They are so situated in the thorax (or chest) that the air *must* enter into them whenever the cavities of the thorax are enlarged. The process of breathing is performed thus: When we INHALE, the thorax (or chest) is expanded; in consequence of which a *vacuum is formed round the lungs*, and the heavy external air instantly enters (through the mouth and throat) *to supply* this vacuum.

When we EXHALE, the thorax *contracts* again; in consequence of which it can no longer contain the *same quantity* of air as it did before, and some of it is necessarily *expelled.* When this expulsion of air takes place, the lungs and *muscular fibres* of the windpipe and gullet *contract* in order to assist the process.

1569 *To what may the mechanism of the lungs in respiration be compared?*

To the *action of a bellows.*

1570 *Do we respire or absorb and expel oxygen in any other way than through the lungs?*

We breathe also in a degree through the pores of the skin, absorbing oxygen and expelling carbonic acid.

1571 *Do extensive burns on the surface of the body frequently produce diseases of the lungs?*

They do.

1572 *Why should extensive burns on the surface of the body tend to produce diseases of the lungs?*

While in a condition of health, the skin tranquilly aids the lungs in the expulsion of *carbonic acid* from the body; but the portion of the skin which has been scorched by an extensive burn, no longer being able to perform that function, the lungs are obliged to assume an *extra duty*, and suffer as a consequence of their exertion.

1573 *If, by neglect of washing, we suffer the skin to become covered with impurities, do we not disturb the healthy action of the system?*

We *do;* there is no better-established law of health, than that the surface of the whole body should be *kept clean* and free from all impurities.

1574 *If the carbon taken from the system through the agency of the lungs be not restored, what is the consequence?*

Starvation ensues.

1575 *How does the oxygen we inhale mingle with the blood?*

The oxygen of the air is *absorbed* in the lungs by the *blood*, and imparts to it a bright red color.

1576 *How does oxygen convert the color of blood into a bright red?*

The *coloring* matter of the blood is formed by very *minute globules* floating in it. The oxygen uniting with these globules changes their color to a *bright red.* The blood contains *iron*, and this metal is supposed to play an important part in the coloration of the blood.

1577 *What color is the blood before it is oxidized in the lungs?*

A *dark purple;* the oxygen turns it to a *bright red.*

1578 *Do plants respire as well as animals?*

They *do;* and their leaves may be regarded as performing for them *similar offices as the lungs of animals.* They are the breathing organs of plants.

1579 *Is there any difference between the respiration of plants and animals?*

The process of respiration in plants is exactly the *reverse* of that in animals. Animals *absorb oxygen*, and *give out carbonic acid;* plants, on the contrary, *absorb carbonic acid*, and *return oxygen.*

1580 *It is estimated that the population of London adds to the atmosphere daily* 4,500,000 *pounds of carbonic acid: how is this immense quantity of deleterious gas removed from the atmosphere?*

Principally through the agency of *plants*, which absorb it.

1581 *Do water-plants purify and free water from carbonic acid in the same manner that land-plants purify the atmosphere?*

The respiration of fishes produces *carbonic acid*, and unless this is removed from the water, *animal life* will *cease to exist* in it. Water-plants absorb the carbonic acid from the water, and restore the oxygen.

1582 *During bright weather, the leaves of water-plants, it will be noticed, are covered with little bubbles: what are these bubbles?*

Oxygen gas, liberated by the organs of the plant.

1583 *It is good policy, in fountains and reservoirs of water, to free them wholly from the presence of vegetable and animal organisms?*

It is *not:* they are both *dependent on one another*, and the joint action of the two serves to keep the water pure and wholesome.

1584 *What is the cause of animal heat?*

The *oxygen* of the atmosphere, received into the blood in the lungs, and *circulated throughout every part of the animal body*, acting upon the elements of the *food*, is the chief source of animal heat.

1585 *Why does oxygen received into the blood produce heat?*

Through the medium of the *capillary vessels* oxygen absorbed from the atmosphere unites with carbon and hydrogen. This union is a species of combustion, and produces heat in the same manner as when oxygen unites with fuel in an ordinary fire.

1586 *What are the capillary vessels?*

Minute bloodvessels or tubes as small as hairs running *all over the body;* they are called capillary from the Latin word *capillaris*, "like a hair."

1587 *Do these capillary vessels run all over the human body?*

Yes. Whenever *blood flows from a wound*, some vein or vessel must be *divided;* and as you can bring blood from any part of the body by a very slight wound, these little vessels must run through every part of the human frame.

1588 *How do hydrogen gas and carbon get into these very small vessels?*

The food we eat is converted into blood, and blood contains both *hydrogen* and *carbon.*

1589 *Does this combustion, and the consequent production of animal heat, take place in every part of the body?*

In the animal body, heat is produced only in those parts to which *arterial blood*, and with it the *oxygen* absorbed in respiration, is *conveyed.*

1590 *Why is there no heat developed in hair, wool, and feathers?*

Because they receive no *arterial blood*, and therefore in them no heat is developed.

1591 *What two kinds of blood are there in the animal body?*

Arterial blood and *venous blood.*

1592 *What is the difference between the two?*

The arterial blood going from the lungs *conveys the oxygen* which it has absorbed in the lungs *to the capillary vessels.* In these the combustion takes place, and the color of the blood changes from a bright to a dark red color.

1593 *What becomes of the blood after it has given up its oxygen to the hydrogen and carbon in the capillary vessels?*

It enters the *veins*, carrying with it the products of combustion. The venous blood passes to the lungs, throws off the products of combustion, absorbs more oxygen, becomes converted into arterial blood, with a renewal of color, and is again returned into the system.

1594 *What becomes of the carbonic acid gas formed in the human blood?*

The *lungs throw off* almost all of it *into the air*, by the act of *respiration.*

1595 *Does the heat of the human body arise from the same cause as the heat of fire?*

Yes, precisely. The *carbon of the blood* combines with the *oxygen of the air inhaled*, and produces *carbonic acid gas*, which action developes heat.

1596 *If animal heat is produced by combustion, why does not the human body burn up like a coal or candle?*

It actually *does so.* Every muscle, nerve, and organ of the body actually *wastes away* like a *burning candle;* and (being reduced to air and ashes) is rejected from the system as useless.

1597 *If every bone, muscle, nerve, and organ is thus consumed by combustion, why is not the body entirely consumed?*

It would be so, unless the parts destroyed were perpetually renewed; but as a lamp will not go out so long as it is *supplied with fresh oil*, neither will the *body* be consumed so long as it is *supplied with sufficient food.*

1598 *What is the principal difference between the combustion of a fire or lamp, and that of the human body?*

In the human body, the combustion is effected at a much lower temperature, and is carried on more *slowly*, than it is in a lamp or fire.

1599 *Why is a dead body cold?*

Because air is no longer conveyed to the lungs after respiration has ceased; and therefore animal heat is no longer generated *by combustion.*

1600 *Why do we perspire when very hot?*

The pores of the body are like the safety-valves of a steam-engine; when the heat of the body is very great, some of the combustible matter of the blood is *thrown off* in perspiration, and the heat of the body is thereby reduced.

1601 *Why does exercise make us warm?*

Because we inhale air more rapidly when we exercise, and cause the blood to pass more rapidly through the *lungs* in contact with it.

1602 *Why does inhaling air rapidly make the body feel warm?*

Because more oxygen is introduced into the body; in consequence of which the combustion of the blood is *more rapid*, the blood itself *more heated*, and every part of the body is made warmer.

1603 *When a man is starved what part of the body goes first?*

First the fat, because it is the most combustible; then, the muscles; last of all, the brain; and then the man dies, like a *candle which is burnt out.*

1604 *Why does a man shrink when starved?*

Because the *capillary fires* feed upon the human *body* when they are not supplied with food-fuel. A starved man shrinks *just as a fire does* when it is not supplied with fuel.

1605 *What is fuel of the body?*

Food is the *fuel of* the *body.* The *carbon of the food*, mixed with the *oxygen of the air*, evolves heat in the same way that a fire or candle does.

1606 *Why does hard work produce hunger?*

Because it produces quicker respiration; by which means a *larger amount of oxygen is introduced into the lungs*, and the *capillary combustion increased.* Hunger is the *notice* (given by our body) to remind us that our *food-fuel* must be *replenished.*

1607 *Why do persons feel lazy and averse to exercise when they are half-starved or ill fed?*

Because desire for muscular action *ceases* when the body is *not supplied* with *nutritious food.*

1608 *Why do we like strong meat and greasy food when the weather is very cold?*

Because strong meat and grease contain large proportions of carbon and hydrogen, which (when burned in the blood) produce a larger amount of heat than any other kind of food.

1609 *Why are the Esquimaux so passionately fond of train oil and whale blubber?*

Because oil and blubber contain large quantities of carbon and hydrogen, which are exceedingly combustible; and as these people live in climates of *intense cold*, the heat of their bodies is increased by the greasy nature of their food.

1610 *Why do we feel lazy and averse to activity in very hot weather?*

Because muscular activity *increases the heat* of our body by *quickening respiration*, and lessens our desire for active exertion.

1611 *How much more carbon do we throw off from the system by respiration in winter than in summer?*

Full *one-eighth more.*

PART VII.

LIGHT, AND HOW WE SEE.

CHAPTER I.

NATURE AND LAWS OF LIGHT.

1612 *Through what agency alone are we enabled to enjoy the sense of sight?*

Through the agency of light.

1613 *What is light?*

Light is now believed to be caused by the agitation, vibration, or undulation of an elastic fluid which is supposed to occupy and pervade all space. We call this supposed fluid ether, and its undulations or vibrations, reaching the eye, affect the optic nerve, and produce the sensation which we call light.

1614 *What analogy is there between the eye and the ear?*

The vibrations or undulations of the *ether* pass along the space intervening between the visible object and the eye in the *same manner* that the undulations of the *air*, produced by a sounding body, pass through the air between this body and the ear.

1615 *If we collect a large quantity of light in one point by means of a glass, and throw it upon the most sensitive balance, does it indicate any perceptible weight?*

It does *not*, in the *slightest degree*.

1616 *What are the chief sources of light?*

The *sun*, the *stars*, *fire* or *combustion*, *electricity*, and *phosphorescence*.

1617 *With what velocity does light move through space?*

With a velocity of *one hundred and ninety-two thousand miles* in a *second* of time.

1618 *Does all light travel equally fast?*

Yes; the light of the sun, the light of a candle, or the light from houses, trees, and fields.

1619 *How long a time does it require for light to pass from the sun to the earth?*

Eight minutes and thirteen seconds.

1620 *How much time is required for a ray of light to traverse the space intervening between the nearest fixed stars and the earth?*

More than *three years;* and from the farthest nebulæ hundreds of years will be required.

1621 *What, therefore, would be the consequence if one of the remote fixed stars were to-day "blotted from the heavens?"*

Several *generations* of the earth would *pass away* before the obliteration could be known to man.

1622 *In what manner do the moon and the planets give light?*

They shine only by means of the *sun's light*, which is *reflected* from their surfaces.

1623 *Where does the light of houses, trees, and fields come from?*

The light of the *sun* (or of some artificial light) is *reflected* from their *surfaces.*

1624 *Why are some surfaces brilliant (like glass and steel) and others dull, like lead?*

Those surfaces which *reflect the most light* are the most *brilliant;* and those which *absorb* light are *dull.*

1625 *How does the velocity of light compare with the speed of a locomotive?*

Light passes from the sun to the earth in about *eight minutes;* a locomotive engine, travelling at the rate of a mile in a minute, would require upwards of *one hundred and eighty* years to accomplish the same journey.

1626 *How does the light of the full moon compare with that of the sun?*

It is estimated to be *three hundred thousand* times weaker than sunlight.

1627 *The velocity of light is demonstrated by observations on the satellites of Jupiter. Will you explain how this can be proved?*

The earth revolves around the sun in an orbit of which the sun is the centre. We are able to calculate the exact time when an observer standing in the centre of the earth's orbit,—that is, in the sun, would see an eclipse of Jupiter's satellite; but as the earth moves round the sun in its orbit, it is brought at one time ninety-five million of miles nearer Jupiter than the sun is, and at another time it is carried ninety-five millions of miles further off. Now, when the earth is nearest to Jupiter, the eclipse takes place eight minutes in advance of the calculated time, and when it is ninety-five millions of miles farther off, the eclipse occurs eight minutes later than the calculated time. This delay is occasioned by the fact, that in the one case the light coming from the satellite to the earth has to traverse a much greater distance than in the other; and if the light requires eight minutes, or 480 seconds, to move over 95,000,000 of miles, it will require one second to move over 197,000 miles, or, with more exact data, 192,000 miles in one second.

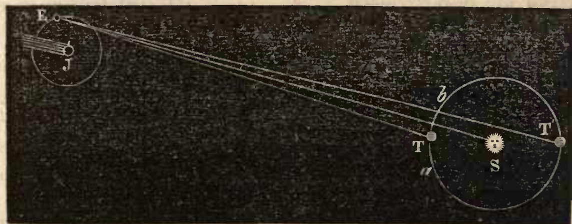


Fig. 50.

The explanation above given will be made clear by reference to the following diagram, *Fig.* 50. *S* represents the sun, *a b* the orbit of the earth, and *T T'* the position of the earth at different and opposite points of its orbit. *J* represents Jupiter, and *E*, its satellite, about to be eclipsed by passing within the shadow of the planet. Now the time of the commencement or termination of an eclipse of the satellite, as stated from calculation in tables, is the instant at which the satellite would appear to enter or emerge from the shadow, if it could be seen by an observer from the sun, *S*. If the transmission of light were instantaneous, it is obvious that the light coming from Jupiter's satellite, *E*, would be seen at the same moment at the points *T*, *S* and *T'*. But repeated observation shows that the eclipse takes place eight minutes earlier than the calculated period when the earth is in the nearest point of its orbit, as at T, and eight minutes later when she is in the opposite part of her orbit, as at T', the difference in the distance of these two points from Jubiter being 190,000,000, of miles.

1628 *Why can a thousand persons see the same object at the same time?*

Because it throws off from its surface an infinite number of rays in all directions; and one person sees *one* portion of these rays, and another person *another*.

1629 *Why can we not see the stars in the day-time?*

Because the light of the sun is so powerful that it *eclipses* the feeble light of the *stars;* in consequence of which they are invisible by day.

1630 *In what manner is light propagated?*

In *right lines* from every luminous point, every such line being called a *ray* of light.

1631 *What do we mean by a pencil of light?*

A *collection of radiating lines* or rays, as seen in *Fig.* 51.

Fig. 51.

1632 *What is darkness?*

The *absence of light.*

1633 *What is a shadow?*

A shadow is the name given to the *comparative darkness* of places or objects, which are *prevented* by intervening things from receiving the *direct rays* of some luminous body shining on the objects around.

1634 *Why cannot we see through a crooked tube as well as through a straight one?*

Because light moves only in *straight lines.*

1635 *What is the philosophy of taking aim with a gun or arrow?*

In taking aim with a gun or arrow, we proceed upon the supposition that *light moves* in *straight lines*, and try to make the projectile go to the desired object as nearly as possible by the *path* along which the *light comes from the object to the eye.*

1636 *Why does a carpenter look along the edge of a plank to see if it is straight?*

If the edge be straight and uniform, the light from all points of the edge will come to the eye *regularly* and *uniformly;* if irregularities, however, exist, they will cause the light to be *irregular*, and the eye at once notices the confusion and the point which occasions it.

37 *What is a mirror?*

Any substance *reflecting light.* The term is generally applied to glass covered on the back with quicksilver.

1638 *When light falls upon a body, in what three ways may it dispose of itself?*

It may be *reflected*, *refracted*, or *absorbed.*

1639 *What do we mean when we speak of light being reflected?*

When a ray of light strikes against a surface, and is caused to *turn back* or *rebound* in a direction different from whence it proceeded, it is said to be *reflected.*

1640 *Why do we see ourselves in a mirror?*

Because the rays of light from our face *strike* against the glass, and (instead of being transmitted) are reflected, or sent back again to our eye.

1641 *Why are the rays of light reflected by a mirror?*

Because they cannot *pass through* the impenetrable *metal* with which the back of the glass is covered; so they rebound back, just as a marble would do if it were thrown against a wall.

1642 *When a marble is rolled towards a wall, what is the path through which it runs called?*

The line of *incidence.*

1643 *When a marble rebounds back again, what is the path it then describes called?*

The line of *reflection.* (See *Fig.* 52.)

If A B be the line of incidence, then B E is the line of reflection; and *vice versâ.*

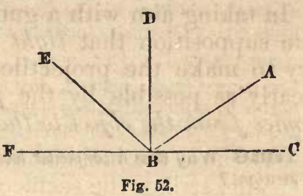


Fig. 52.

1644 *When the light of our face goes to the glass, what is the path rough which it goes called?*

The line of *incidence.*

1645 *When the light of our face is reflected back again from the mirror, what is this returning path called?*

The line of *reflection.*

1646 *What is the angle of incidence?*

The angle between the line of *incidence* and the *perpendicular.*

1647 *What is the angle of reflection?*

The angle between the line of *reflection* and the perpendicular. (*See Fig.* 52.)

Let F B C (*Fig.* 53) be any surface; D B a perpendicular to it. If a marble were thrown from E to B, and bounded back to A, then E B D would be the angle of incidence, and D B A the angle of reflection.

1648 *Why does the image of any object in water always appear inverted?*

Because the angles of incidence being always equal to the angles of reflection, the light of the object, reflected to our eyes from the surface of the water, comes to us with the same direction as it would have done, had it proceeded directly from an inverted object in the water.

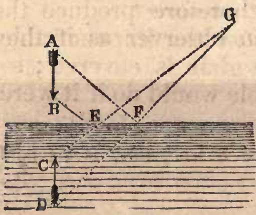


Fig. 53.

In *Fig.* 53, the light proceeding from the arrow-head, A, strikes the water at F, and is reflected to G and that from the barb, B, strikes the water at E, and is reflected to G. A spectator standing at G will see the reflected lines, E G and F G, as if they proceeded directly from C and D. Now we always judge of the position of an object according to the direction in which the rays of light representing it come to the eye, and for this reason the image of the arrow, A B, reflected from the surface of water, appears to be located at C D. It is also plain that A (the more *elevated* object) will strike the water, and be projected from it more perpendicularly than the point B; and therefore the image will seem inverted.

1649 *If we lay a looking-glass upon the floor, with its face uppermost, and place a candle beside it, why will the image of the candle seen in the mirror by a person standing opposite to the candle, seem as much below the surface of the glass as the candle itself stands above the glass?*

Because the incident ray coming from the top of the candle, strikes the surface of the glass, and is reflected in the same direction that a ray of light would have taken, had it really come from a candle situated as much below the surface of the glass, as the first candle was above the surface. This fact will be clearly shown by referring to *Fig.* 54.

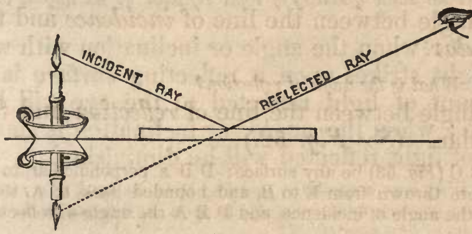


Fig. 54.

1650 *Why, when we look into a plane mirror (the common looking-glass) does our image appear to be at the same distance behind the surface of the glass, as we are before the surface?*

Because the lines and angles of incidence being always equal to the lines and angles of reflection, the rays which proceed from each point of our body before the mirror will, after reflection, proceed as if they came from a point holding a corresponding position behind the mirror;—and therefore produce the same effect upon the eye of an observer as if they actually had come from that point.

For this reason our reflection in a mirror seems to approach us as we walk towards it, and to retire from us as we retire.

The whole subject of the reflection of images being generally of difficult comprehension by most persons, *Fig.* 55 is introduced as a means of further explanation.

Let A be a part of an object placed before a looking-glass M N. Let A B and A C be two rays diverging from it, and reflected from B and C to an eye at O. After reflexion

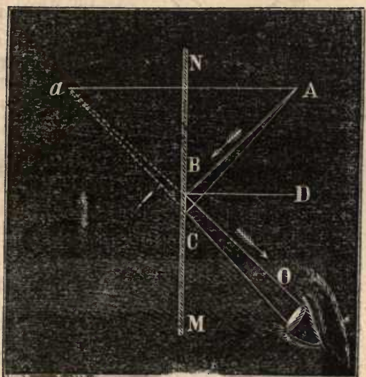


Fig. 55.

they will proceed as if they had issued from a point *a* as far behind the surface of the looking-glass, as A is before it—that is to say, the distance A N will be equal to the distance *a* N. In seeing an object with the eye, we fix upon its position according to the direction in which the rays of light coming from it proceed, and do not take into account the fact that the rays have been reflected from their original course.

1651 *Is the same quantity of light reflected at all angles, or inclinations?*

It is not: when the angle or inclination with which a ray of light strikes upon a reflecting surface is great, the amount of light reflected to the eye will be considerable; when the angle, or inclination is small, the amount of light reflected will be diminished

1652 *Why does a spectator, standing upon the bank of a river, see the images of the opposite bank, and objects upon it reflected in the water, but not the images of any near object?*

Because the rays of light coming from distant objects strike the surface of the water very obliquely, and the light reflected is sufficient to make a sensible impression upon the eye, while the light proceeding from near objects strikes the water with little obliquity, and the light reflected is not sufficient to make a sensible impression upon the eye.

This fact may be clearly seen by reference to *Fig.* 56.

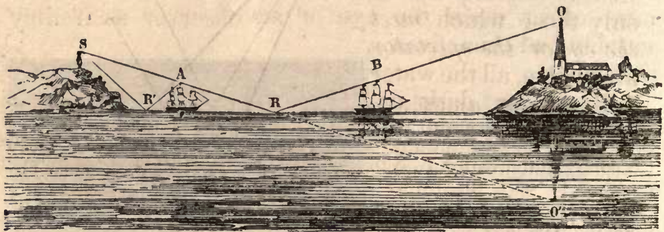


Fig. 56.

Let S be the position of the spectator; O and B the position of distant objects. The rays O R and B R which proceed from them, strike the surface of the water very obliquely, and the light which is reflected in the direction R S is sufficient to make a sensible impression upon the eye.

But in regard to objects such as A placed near the spectator, they are not seen reflected, because the rays A R′ which proceed from them strike the water with but little obliquity; and consequently, the part of their light which is reflected in the direction R′ S, towards the spectator, is not sufficient to produce a sensible impression upon the eye.

1653 *Why do windows seem to blaze at sunrise and sunset?*

Because glass is a good *reflector of light*, and the rays of the sun (striking against the window-glass) are *reflected*, or thrown back.

1654 *On a lake of water the moon seems to make a path of light towards the eye of the spectator, while all the rest of the lake seems dark: why is this?*

The reason of this appearance is that every little wave, in an extent perhaps of miles, has some part of its rounded surface with the direction or obliquity which, according to the required relation of the angles of incidence and reflection, fits it to reflect the light to the eye, and hence every wave in that extent sends its momentary gleam, which is succeeded by others.

1655 *In a sheet of water at noon, the sun appears to shine upon only one spot, and all the rest of the water seems dark: why is this?*

Because the rays fall at various degrees of obliquity on the water, and are reflected at *similar angles*; but as only those which *meet the eye of the spectator* are visible, all the water will appear dark except *that one spot*.

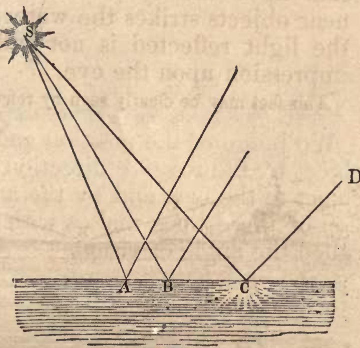


Fig. 57

Here, of the rays S A, S B, and S C, only the ray S C meets the eye of the spectator D. The spot C, therefore, will appear luminous to the spectator D, but no other spot of the water A B C.

1656 *Why can we not see into the street or road when candles are lighted?*

1. Because glass is a reflector, and throws the candle-light *back into the room* again; and

2. The pupil of the eye (having become *contracted* by the light of the room) is *too small* to collect rays

enough from the dark street to enable us to *see into it.*

1657 *Why do we often see the fire reflected in our windows in winter-time?*

Because glass is a *good reflector*, and the rays of the fire (striking against the window-glass) *are reflected back into the room again.*

1658 *If the shadow of an object be thrown on a wall, the closer the object is held to the candle, the larger will be its shadow: why is this?*

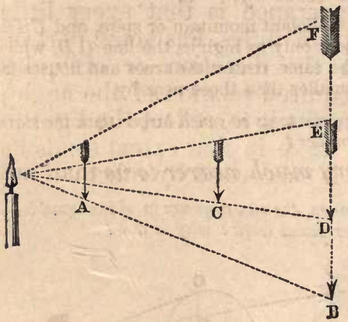


Fig. 58.

Because the rays of light *diverge* (from the flame of a candle) *in straight lines*, like lines drawn from the centre of a circle.

Here the arrow A, held close to the candle, will cast the shadow B F on a wall; while the same arrow, held at C, would cast only the little shadow D E.

1659 *How do we judge of the position, distance, and size of an object?*

We judge of the position and distance and size of an object by the relative direction of lines drawn from the object to the eye, and by the angle which the intersection of these lines makes with the eye. This angle is called the angle of vision.

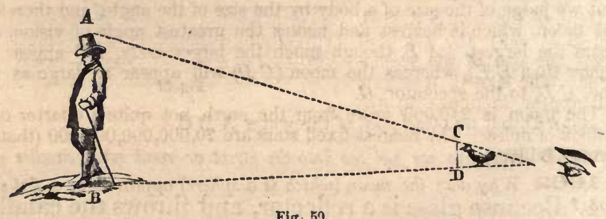


Fig. 59.

The student will bear in mind that an angle is simply the inclination of two lines without any regard to their length. Thus, in *Fig.* 59, the inclination of the lines, caused by rays of light proceeding from *A* and *B*, and from *C* and *D*, and meeting at the eye, forms an angle at the point of intersection, which is the eye. This angle is the angle of vision. As the inclination of the ines proceeding from *A* and *B*, and from *C* and *D*, is the same, the angles will be equal, and the man and the bird will appear of the same size.

1660 *Why does a man on the top of a mountain or church-spire seem to be no larger than a crow?*

Because the angle made in our eye by the *perpendicular height of the man* at that distance is no larger than that made by a *crow close by.*

Let *A B* (*Fig.* 59) be a man on a distant mountain or spire, and *C D* a crow close by, the man will appear only as high as the line *C D*, which is the height of the crow. For the same reason the trees and houses far down a street or avenue appear smaller than those near by.

1661 *Why does the moon appear to us so much larger than the stars, though, in fact, it is a great deal smaller?*

Because the moon is *very much nearer to us* than any of the stars.

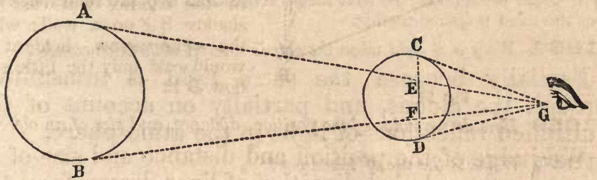


Fig. 60.

Let *A B* represent a fixed star, and *C D* the moon. The angle of vision, *A G B*, which the fixed star, *A B*, makes with the eye is evidently less than the angle of vision, *C G D*, which the moon makes with the eye. But we judge of the size of a body by the size of the angle, and therefore the moon, which is nearest and makes the greatest angle of vision, appears the largest. *A B*, though much the larger body, will appear no bigger than *E F;* whereas the moon (*C D*) will appear as large as the line, *C D*, to the spectator, *G*.

The moon is 240,000 miles from the earth, not quite a quarter of a *million* of miles. The nearest fixed stars are 20,000,000,000,000 (that is, twenty billions).

1662 *Why does the moon (which is a sphere) appear to be a flat surface?*

Because it is *so far off* that we cannot distinguish any difference between the *length of the rays* issuing from the *edge* and those which issue from the *centre.*

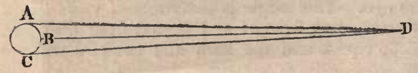


Fig. 61.

The rays $A\ D$ and $C\ D$ appear to be no longer than the ray $B\ D$; but if all the rays seem of the same length, the part B will not seem to be *nearer* to us than A and C; and therefore $A\ B\ C$ will look like a flat or straight line. The rays $A\ D$ and $C\ D$ are 240,000 miles long. The ray $B\ D$ is 238,910 miles long.

1663 *An object in the shade is not so bright and apparent as an object in the sun: why is it not?*

Because objects in the shade are seen by reflected light *reflected*; that is, the light is *twice* reflected; and, as the rays of light are always absorbed in some measure by every substance on which they fall, and also scattered by irregular reflections, therefore in the two reflections much light is lost, and the object is seen with less distinctness.

Part of the rays are absorbed, and part are scattered in all directions by irregular reflections; so that rarely more than *half* are reflected, even from the most polished metals.

1664 *Why is it light when the sky is covered with thick clouds?*

Partially because the sun's light is transmitted through the clouds, and partially on account of the multiplied reflections of light in the atmosphere.

1665 *What is the use of telescopes?*

They *gather together* the rays of light, and a greater number are thus brought to the eye.

1666 *How can these rays be gathered together?*

Rays of light diverge—that is, spread out in all directions—from a luminous object. The number of these diverging rays which will enter the eye is limited by the size of the pupil. But before they reach the eye, they may be received upon a glass lens of a convex form, which will have the effect of collecting them into a space less in magnitude than the pupil of the eye. If the eye be placed where the rays are thus collected, all the light will enter the pupil.

The light which produces vision, as will be more fully explained hereafter, enters the eye through a circular opening called the pupil, which is the black circular spot surrounded by a colored ring, appearing in the

How telescopes assist the sight.

Fig. 62.

Fig. 63.

centre of the front of the eye. Now, as the rays of light proceeding from an object diverge, or spread out, the number which will enter the eye will be limited by the size of the pupil. At a great distance from an object, as will be seen in *Fig.* 62, few rays will enter the eye; but if, as in *Fig.* 63, we place before the eye a piece of glass, called a lens, so constructed as to collect all the diverging rays together, the light will be concentrated at one point, and in sufficient quantity to enable us to see distinctly.

1667 *Why do telescopes enable us to see objects invisible to the naked eye?*

Because they gather together more luminous rays from obscure objects than the *eye* can, and form a bright image of them in the tube of the telescope, where by means of lenses they are magnified.

1668 *When a ship (out at sea) is approaching the shore, why do we see the small masts before we see the bulky hull?*

Because the *earth is round;* and the *curve* of the sea *hides the hull* from our eyes after the tall *masts* have become visible.

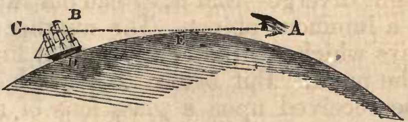


Fig 64.

Here only that part of the ship above the line A C can be seen by the spectator, A; the rest of the ship is hidden by the swell of the curve D E.

The diminution of the size of a ship seen at sea, owing to the convexity of the earth and the distance of the observer, is also illustrated in *Fig.* 65.

1669 *What is meant by the refraction of light?*

Light traverses a given transparent substance, such as

Fig. 65.

air, water, or glass, in a straight line, provided no reflection occurs and there is no change of density in the composition of the medium; but when light passes from *one medium into another*, or from one part of the *same medium* into *another* part of a *different density*, it is *bent* from a straight line, or refracted.

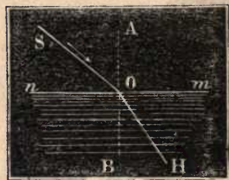


Fig. 66.

In *Fig.* 66, suppose *n m* to represent the surface of water, and S O a ray of light striking upon its surface. When this ray S O enters the water, it will no longer pursue a straight course, but will be refracted, or bent towards the perpendicular line, A B, as in the case of S O H. The denser the water, or other fluid, may be, the more the ray S O H will be refracted, or turned towards A B.

1670 *Does air possess the property of refracting light?*

Yes; the more *dense* the air, the greater is its *refractive* power.

1671 *Why does the part of a stick immersed in the water appear bent or broken?*

The water and the air being of different densities, the rays of light proceeding from the part of the stick contained in the water are *refracted*, or caused to *deviate* from a *straight line* as they pass from the water into the air; consequently that portion of the stick immersed in the water will appear to be *lifted up*, or to be *bent* in such a manner as to form an angle with the part out of the water.

Fig. 67.

The bent appearance of the stick in water is represented in *Fig.* 67. For the same reason, a spoon in a glass of water, or an oar partially immersed in water, always appears bent.

1672 *Why does a river always appear more shallow than it really is?*

Because the light proceeding from the bottom of the river is *refracted* as it emerges out of the water, and causes the bottom to appear elevated.

1673 *How much deeper is a river than it seems to be?*

About one-third. If, therefore, a river seems only four feet deep, it is really six feet deep.

Many persons get out of their depth in bathing in consequence of this deception.

The following simple experiment illustrates the effect of refraction:—Place a silver coin, *m*, at the bottom of a basin, *Fig.* 68. The rays, *i i*, proceeding to the eye from the silver surface, render the coin visible. The point *a*, the eye, is then moved farther back, so that the edge of the basin obstructs the direct rays, and of course the coin is no longer seen. If an attendant carefully pours water into the basin, so that the object is not moved, it will presently, as the water rises in the basin, become again visible. This arises from the *refraction of the rays* by the water, the image, indeed, appearing at *n* instead of at *m*.

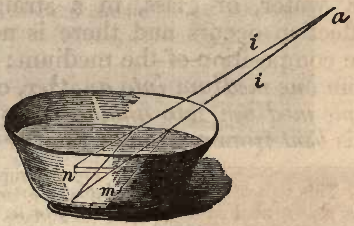


Fig. 68

1674 *Is a ray of white light simple or compound?*

Every ray of white light is *compounded* of other rays of *colored light.*

1675 *Into how many parts may a ray of light be divided?*

Into three parts: *blue*, *yellow*, and *red.*

These three colors, by combination, make seven: 1, *red;* 2, *orange* (or red and yellow); 3, *yellow;* 4, *green* (or yellow and blue); 5, *blue;* 6, *indigo* (a shade of blue); and, 7, *violet* (or blue and red).

1676 *How is it known that a ray of light consists of several different colors?*

Because if a ray of light be cast upon a triangular piece of glass (called a prism), it will be distinctly divided into seven colors: 1, red; 2, orange; 3, yellow; 4, green; 5, blue; 6, indigo; and, 7, violet.

1677 *Why does a prism divide a ray of light into various colors?*

Because all these colors are refracted, or bent out of their course differently. Red is refracted *least,* and blue the *most;* therefore, the *blue* ray will be bent to the *top* of the prism, and the *red* will remain at the *bottom*.

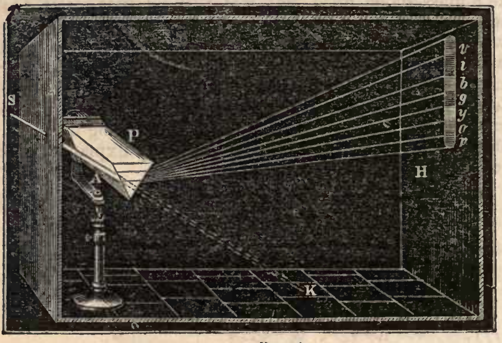


Fig. 69.

This separation of a ray of solar light into different colors, by refraction, is represented in *Fig.* 69. A ray of light, *S A*, is admitted through an aperture in a window-shutter into a darkened chamber, and caused to fall on a prism, *P*. The ray thus entering would, if allowed to pass unobstructedly, have moved in a straight line to the point *K*, on the floor of the room; but the prism being so placed that the ray may enter and quit it at equal angles, it will be refracted in such a manner as to form on the opposite side of the room an oblong image called the solar spectrum, divided horizontally into seven colored spaces or bands of unequal extent, succeeding each other in the order represented: *red, orange, yellow, green, blue, indigo, violet.*

1678 *Are the colored rays, once separated and refracted from the prism, capable of being analyzed by refraction again?*

They are *not*, and are hence designated as *primary colors.*

1679 *If the seven different colors as separated by the prism be again collected together, what will they form?*

White light.

1680 *To what is the great brilliancy of the diamond and other precious stones due?*

To their power of *refracting light;* they are also artificially cut in such a manner as to form a series of *prisms,*, which separate the rays of light falling on them into their *component colored rays.*

1681 *What is a rainbow?*

The rainbow is a *semicircular band* or *arc*, composed

Production and explanation of the rainbow.

of the different colors, generally exhibited upon the clouds during the occurrence of rain in sunshine.

If we take a glass globe filled with water, and suspend it at a certain height in the solar rays above the eye, a spectator standing with his back to the sun will see the refraction and reflection of red light; if, then, the globe be lowered slowly, the observer retaining his position, the red light will be replaced by orange, and this in its turn by yellow, and so on, the globe at different heights presenting to the eye the seven primitive colors in succession. If now, in the place of the globe occupying different positions, we substitute drops of water, we have a ready explanation of the phenomena of the rainbow.

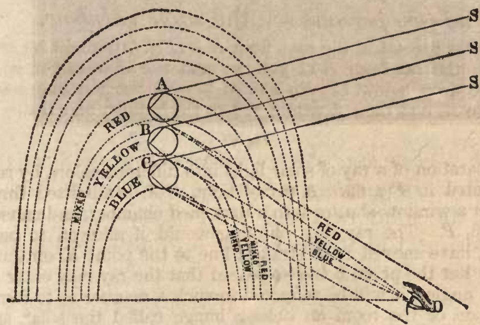


Fig. 70.

Let *A*, *B*, and *C* be three drops of rain; *S A*, *S B*, and *S C*, three rays of the sun. *S A* is divided into three colors; the blue and yellow are bent *above* the eye, *D*, and the *red* enters it.

The ray, *S B*, is divided into three colors; the blue is bent *above* the eye, and the red falls *below* the eye, *D*, but the *yellow* enters it.

The ray, *S C*, is also divided into the three colors. The blue (which is bent most) enters the eye; and the other two fall below it. Thus the eye sees the blue of *C*, and of all drops in the position of *C;* the yellow of *B*, and of all drops in the position of *B;* and the red of *A*, and of all drops in the position of *A;* and thus it sees a rainbow.

1682 *What is the occasion of the rainbow?*

The rainbow is produced by the *refraction* and *reflection* of the solar rays in the *drops* of *falling rain.*

1683 *What are the conditions necessary in order that we may see a rainbow?*

The rainbow can be seen only when it *rains*, and in that point of the heavens which is *opposite* to the *sun.* It is necessary also that the sun should not have too great an *altitude above the horizon.* Hence, within a certain interval each day, no visible rainbows can be formed, on account of the sun's high altitude above the horizon.

1684 *How do we know that the rainbow results from the decomposition of the solar rays by drops of water?*

Because in the case of *cascades* and *water-falls*, the *spray* and the drops of moisture dispersed over the grass and the spiders'-webs produce the *same phenomena.*

1685 *Does every person see the same colors from the same drops?*

No; *no two persons* see the *same rainbow.*

To another spectator, the rays from *S B* (*Fig.* 70) might be *red* instead of yellow; the ray from *S C*, yellow; and the blue might be reflected from some drop below *C*. To a *third* person, the red may issue from a drop above *A*, and then *A* would reflect the yellow, and *B* the blue, and so on.

1686 *Why are there often two rainbows at one and the same time?*

The first, or *primary bow*, is formed by *two refractions* of the solar ray, and *one reflection*, the rays of the sun entering the drops at the *top*, and being reflected to the eye from the *bottom.*

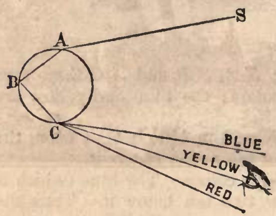


Fig. 71.

Thus in *Fig.* 71, the ray S A of the primary rainbow strikes the drop at A, is refracted or bent to B, the back part of the inner surface of the drop; it is then refracted to C, the lower part of the drop, when it is refracted again, and so bent as to come directly to the eye of the spectator.

The secondary, or outer bow, is produced, on the contrary, by two refractions and *two reflections*, the ray of light entering the drops from the bottom, and being reflected to the eye from the top.

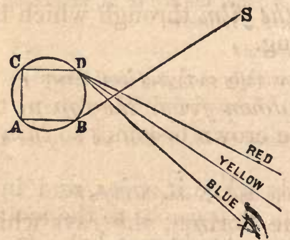


Fig. 72.

Thus in *Fig.* 72, the ray S B of the secondary bow strikes the bottom of the drop at B, is refracted to A, is then reflected to C, is again reflected to D, when it is again refracted or bent, till it reaches the eye of the spectator.

1687 *Why are the colors of the second bow all reversed?*

Because in *one* bow we see

the rays which enter at the *top* of the rain-drops, *refracted from the bottom:*

But in the *other* bow we see the rays which enter at the *bottom* of the rain-drops (after two reflections) *refracted from the top.*

The position and formation of the primary and secondary rainbows are represented in *Fig.* 73. Thus in the formation of the primary bow, the ray of light S strikes the drop *n* at *a*, is refracted to *n b*, thence to *g*, and leaving the drop at this point, proceeds to the eyes of the spectator at O. In the formation of the secondary bow, the ray S′ strikes the drop *p* at the bottom at the point *i*, is refracted to *d*, thence to *f*, and again to *e*, proceeding from the top of the drop, also to the eye of the spectator at O.

The reason why the primary bow exhibits the stronger colors is, because the colors are seen after *one* reflection and *two* refractions; but the colors of the secondary (or upper) rainbow undergo *two* reflections and *two* refractions.

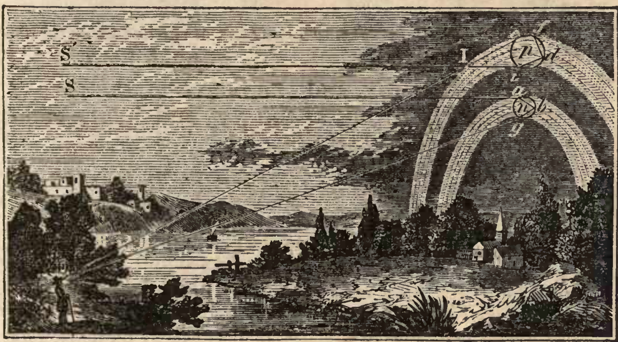


Fig. 73.

1688 *Why does a soap bubble exhibit such a variety of colors?*

Because the *thickness of the film* through which the rays pass is constantly varying.

1689 *Why is a soap bubble so constantly changing its thickness?*

Because the water *runs down from the top* to the bottom of the bubble, till the crown becomes so *thin* as to burst.

1690 *What is the cause of morning and evening twilight?*

When the sun is below the horizon, the rays which strike upon the atmosphere or clouds are *bent down* *towards the earth*, and produce a little light called twilight.

1691 *What is a lens?*

A piece of *glass* or other *transparent substance*, bounded on both sides by polished spherical surfaces, or on the one side by a spherical, and on the other by a plane surface. Rays of light passing through it are made to change their direction, and to *magnify* or *diminish* the appearance of objects at a certain distance.

1692 *How many varieties of lenses are generally recognised?*

Two: *convex* and *concave*.

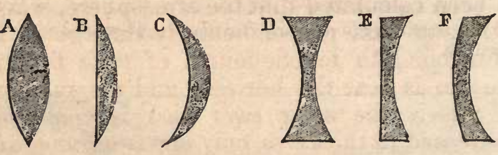


Fig. 74.

Among convex lenses are the double convex A (*Fig.* 74) to which the appellation *lens* was originally applied from its resemblance to a lentil-seed (*lens* in Latin) being bounded by two convex spherical surfaces whose centres are on opposite sides of the lens; the plano-convex B, having one side bounded by a plane surface, and the other by a convex surface; and the meniscus or concavo-convex C, bounded on one side by a concave, and on the other by a convex surface.

There are also three principal varieties of concave glasses; as the double concave D, bounded by two concave surfaces, forming portions of spheres whose centres are on opposite sides of the lens; the plano-concave E, bounded on one side by a plane, and on the other by a concave surface; and convexo-concave F, bounded by a convex surface on one side, and by a concave one on the other.

1693 *What is a focus of light?*

When rays of light continually *approach* each other, as in moving to a point, they are said to *converge*, and the point at which the converging rays *meet* is called the *focus*.

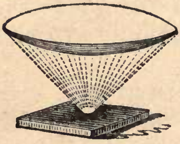


Fig. 75.

1694 *What sort of a lens is a common burning-glass?*

A *double convex* lens.

Fig. 75 represents the action of a double convex lens in causing the rays of light to converge and meet at a focus.

1695 *What are transparent bodies?*

Those which do not *interrupt* the passage of light, or which *admit* of other bodies being *seen through* them.

1696 *When is a body said to be opaque?*

When it entirely *prevents* the passage of light.

1697 *Is there any body perfectly transparent?*

No; some light is evidently *lost* in passing even through space, and still more in traversing our atmosphere.

1698 *How much of the sun's light is supposed to be intercepted by the atmosphere?*

It has been calculated that the atmosphere, when the rays of the sun pass perpendicularly through it, intercepts from one-fifth to one-fourth of their light; but when the sun is near the horizon, and the mass of air through which the solar rays pass is consequently vastly increased in thickness, only one *two hundred and twelfth* part of their light can reach the surface of the earth.

1699 *Why is charcoal black?*

Because it *absorbs* all the light which falls upon it, and *reflects* none.

1700 *What becomes of the light which is absorbed?*

This question cannot be satisfactorily answered. In all probability it is *permanently retained* within the substance of the absorbing body.

1701 *To what depth is light supposed to penetrate the ocean?*

It is calculated that sea water loses all its transparency at the depth of *seven hundred and thirty* feet; but a dim twilight must prevail much deeper in the ocean.

CHAPTER II.

STRUCTURE OF THE EYE AND THE PHENOMENA OF VISION.

1702 *What is the structure of the human eye?*

In man the organ of vision consists of two hollow spheres, each about an inch in diameter, filled with certain transparent liquids, and deposited in cavities of suitable magnitude and form in the upper part of the front of the head on each side the nose.

1703 *How is it that we are enabled to move the eye in various directions?*

By means of muscles attached to different points of its surface.

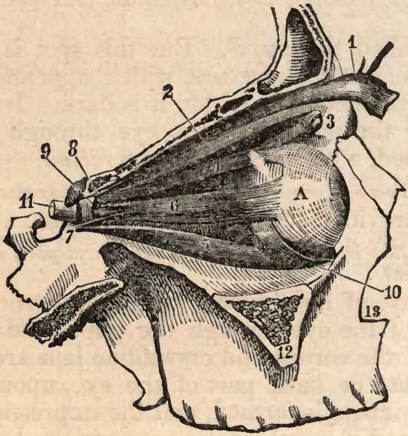


Fig 76.

These are shown in *Fig.* 76, where the external bones of the temple are supposed to be removed in order to render visible the muscular arrangements. The muscle, 1, raises the eye-lid, and is constantly in action while we are awake. During sleep, the muscle being in repose and relaxed, the eye-lid falls and protects the eye from the action of light. The muscle, 4, turns the eye upwards; 5, downwards; 6, outwards; and a corresponding one on the inside, not seen in the figure, turns it inwards. No. 2 and 10 turn the eye round its axis. No. 11 is the great optic nerve, which conveys the sensation to the brain. If this nerve were cut, notwithstanding the eye might be in other respects perfect, the sense of sight would be destroyed.

1704 *Of what parts does the eye consist?*

The eye is of globular form, and is composed of three coats or membranes, called the *sclerotic*, the *choroid*, and the *retina;* and three humors, denominated the *aqueous*, the *crystalline*, and the *vitreous.*

1705 *What is meant by the "retina of the eye?"*

The network which lines the *back of the eye* is called the retina; it is composed of an expansion of the optic nerve.

1706 *What is that portion of the eye called which in some persons is blue, in others gray or hazel?*

It is called the *iris.*

1707 *In the centre of the iris is a circular black opening: what is this called?*

It is called the *pupil.* But this spot is not a black substance, but an *aperture*, which appears black only because the chamber within it is dark. It is properly speaking the *window* of the eye, through which light is admitted, which strikes on the *retina.*

1708 *Does light admitted through the pupil to the retina produce vision?*

Yes, provided the light enter in sufficient quantity.

1709 *How by the arrangement of the several parts of the eye are we enabled to see?*

The rays of light falling upon the cornea, enter the interior of the eye through the pupil, and by the joint action of the cornea and crystalline lens are brought to a focus at the back part of the eye, upon the retina. Here an image is formed, and the impression it makes is conveyed along the optic nerve to the brain.

1710 *What is meant by the "cornea of the eye?"*

All the *outside* of the visible part of the *eyeball.*

Fig. 77 represents the interior construction of the eye. It is composed, in the first place, of the cornea, *a*, a transparent membrane in front of the globe of the eye. Next is the sclerotic coat, *i*, which joins on the cornea, and upon which the external form of the eye depends. The cornea is united to, or fixed in, the sclerotic coat, like the glass into the case of a watch: *d*, *c* represents the iris, with an opening in it, forming the pupil.

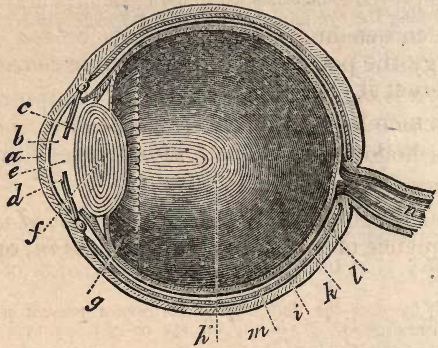


Fig. 77.

Next in order is the aqueous humor, *b*, *e*, in the middle of which is the iris, *d*, *c*. Behind the pupil we have the crystalline lens, *f*, and then the vitreous humor, *h*, filling all the interior of the ball of the eye. *m* indicates the retina, which is an expansion of the optic nerve, *n*. *k* is the choroid coat, a membrane interposed between the retina and the sclerotic coat; it terminates in form in a series of folds or filaments, *g*, called the ciliary ligament or processes.

1711 *Why are some persons near-sighted?*

Because the curvature of the cornea and the crystalline lens is too great, and the rays of light which form the image are brought to a focus before they reach the retina or the back part of the eye. The object, therefore, is not distinctly seen.

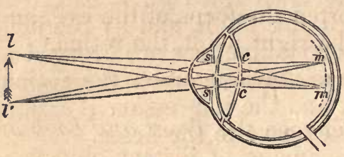


Fig. 78.

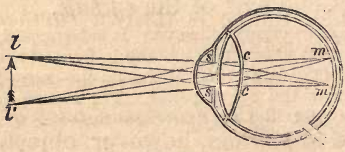


Fig. 79.

Fig. 79 represents the manner in which the image is formed upon the retina in the perfect eye. The curvature of the cornea, *s s*, and of the crystalline lens, *c c*, is just sufficient to cause the rays of light proceeding from the image, *e e*, to converge to the right focus, *m*, upon the retina.

Fig. 78 represents the manner in which the image is formed in the eye of a near-sighted person. The curvature of the cornea, *s s*, and of the crystalline lens, *c c*, is so great that the image is formed at *m m* in advance of the retina.

Explanation of far-sightedness.

1712 *What sort of glasses do near-sighted persons wear?*

If the cornea and crystalline lens be *too convex* (or projecting), the person must wear double *concave glasses* to counteract it.

1713 *What is meant by "double concave glasses?"*

Glasses hollowed-in *on both sides.*

1714 *Why are old people far-sighted?*

Because the humors of their eyes are *dried up by age;* in consequence of which the *cornea sinks in*, or becomes flattened.

1715 *Why does the flattening of the cornea prevent persons seeing objects which are near?*

Because the cornea is *too flat*, and the image of objects is not *completely* formed when their rays reach the *retina;* in consequence of which the image is imperfect and confused.

Fig. 80 represents the manner in which the image is formed in the eye, when the cornea or crystalline lens is flattened. The perfect image would be produced at *m m*, behind the retina, and, of course, beyond the point necessary to secure perfect vision.

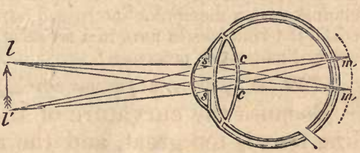


Fig. 80.

1716 *What sort of spectacle-glasses are suitable for old people?*

Double-convex glasses, or those which curve outwards on both sides. These shorten the focus of the eye, and produce an image upon the right point, the retina.

1717 *Why do near-sighted persons bring objects close to the eye in order to see them?*

Because the distance between the *front and back of the eye is so great*, that the image of distant objects is formed in *front* of the *retina;* but when objects are brought *near to the eye*, their image is thrown *farther back*, and made to fall on the retina.

1718 *Why do old people hold objects far off in order to see them better?*

Because the distance between the *front and back of their eyes is not great enough;* when, however, objects are held farther off, it compensates for this defect, and a perfect image is formed on the retina.

Birds of prey are enabled to adjust their eyes so as to see objects at a great distance, and again those which are very near. The first is accomplished by means of a muscle in the eye, which enables them to flatten the cornea by drawing back the crystalline lens; and to enable them to perceive distinctly very near objects, their eyes are furnished with a flexible bony rim, by which the cornea is thrown forward at will, and the eye thus rendered near-sighted.

1719 *Why do persons who are short-sighted in youth, gradually have this failing corrected as they grow old?*

They are short-sighted because the cornea of the eye is *too globular;* but as age advances, the fluids are not secreted as before, the eye becomes *flattened*, and natural sight is *again restored.*

1720 *What is the use of the eyebrows?*

The eyebrows *defend* the eyes from *too strong* a light, and serve to *turn away* substances which might otherwise fall into the eye.

1721 *What is the use of the eyelashes?*

The eyelashes *guard* the eye from *danger*, and *protect* it from *dust* or *insects* floating or flying in the atmosphere.

1722 *Why is the eye pained by a sudden light?*

Because the nerve of the eye is *burdened with rays* before the pupil has had time to contract.

1723 *What is the pupil of the eye?*

The circular black opening in front of the eye.

1724 *Why does it give us pain if a bright light is brought suddenly towards us at night-time?*

Because the *pupil* of the eye *dilates* very much in the dark in order to *admit* more rays.

When therefore a light is brought suddenly before us, the enlarged pupils *overload* the optic nerves with *rays*, which causes pain.

1725 *Why can we bear the light after a few moments?*

Because the pupils *contract again* almost instantly, and adjust themselves to the quantity of light which falls upon them.

1726 *Why can we see nothing when we leave a well-lighted room, and go into the darker road or street?*

Because the pupil (which *contracted* in the bright room) does not *dilate instantaneously;* and the contracted pupil is not able to collect rays enough from the darker road or street to enable us to see objects before us.

1727 *How does light cause the pupil of the eye to contract?*

The pupil of the eye is a round hole in the midst of a movable muscular curtain or screen, called the *iris.* When too much light falls on the nervous retina at the back of the eye, it *irritates* it; and this *irritation* is conveyed to the muscular rings composing the curtain by small nervous fibres, causing them to contract.

1728 *Why do we see better when we get used to the dark?*

Because the pupil *dilates* again, and allows more rays to pass through its aperture; in consequence of which we see more distinctly.

1729 *If we look at the sun for a few moments, why do all other things appear dark?*

Because the nerve of the eye, by looking at the sun, is so affected by the intensity of the light that it requires a few moments to recover its former sensibility.

1730 *Why can we see the proper colors of every object again after a few minutes?*

Because the eye again recovers its sensibility, and accommodates itself to the light around.

1731 *Why can tigers, cats, and owls see in the dark?*

Because they have the power of *enlarging the pupil of their eyes* so as to collect the scattered rays of light; in consequence of which they can see distinctly when it is not light enough for us to see anything at all.

1732 *Why is it that when we press slightly upon the ball of either eye, while viewing an object, we see double?*

Because the *pressure* of the *finger* prevents the ball of one eye from following the motion of the other, and the axis of vision in each eye being different, we see two images.

1733 *Do persons who squint see double?*

They *do;* but practice gives them power of *attending* to the sensation of only *one eye at a time.*

1734 *What is the cause of strabismus, or squinting?*

The *inability* of one eye to follow the *motions* of the other; this may arise from habit, imperfect power in one eye, or some defect in the muscular movements.

1735 *Why, when the eye is violently struck or pressed upon, do we seem to see light?*

Because the *pressure* communicated to the *optic nerve* causes a violent and momentary sensation of light.

1736 *When we say we see an object, what do we in fact do?*

The mind is only taking cognizance of the *picture* or *impression* made on the retina.

1737 *If the mind, in seeing an object, sees in reality only a picture painted on the back of the retina, how is it enabled to judge of magnitudes, distances, etc., the picture being on a comparatively flat surface?*

It is only by *experience*. "I see men as trees walking," said the man born blind, when restored to sight.

1738 *Would a person whose eyes, although perfect, had been covered up from infancy to maturity, be able to see? that is, comprehend any scene or prospect on which he first opened his eyes?*

He would *see the objects*, but could *no more understand them* than a child understands the printed page on which it looks, although every word is clear and distinct.

1739 *Do we see the same lines and surfaces of an object alike with each eye?*

We do *not*.

We may convince ourselves that we do not, by placing two *candles*, for example, in such a *position*, that when they are looked at with the *right* eye, one is made to cover the other; if now we close the right eye and look at them with the *left*, the most remote candle will be no longer screened by the front one, but will be seen about an inch to the left of it.

1740 *Why cannot we count the posts of a fence when we are riding rapidly in a railroad car?*

Every impression, according to the intensity of its effects, *remains* for a certain length of time on the *retina*, and a *measurable period* is necessary to produce the *impression*. The light from each post falls upon the eye in such rapid succession, that the different images become confused and blended, and we do not obtain a distinct vision of the particular parts.

Why the sun and moon seem larger on the horizon than overhead.

1741 *Why do the sun and moon seem larger at their rising and setting than at any other time?*

The appearance is an illusion, in consequence of terrestrial objects being placed in close comparison with them at one time, and not at the other.

1742 *Is this illusion an optical one, or a mental illusion?*

A mental one, since the organs of vision do not present to us a larger image of the moon or sun in the horizon than in the zenith.

1743 *What do we mean by the horizon?*

The circle or *line* where the earth and sky *appear to meet.*

1744 *What do we mean by the zenith?*

The point or part of the heavens *immediately overhead.*

1745 *Is the moon nearer or farther from us when upon the horizon?*

When the moon is on the horizon, it is about *four thousand* miles farther from us than when in the zenith; its apparent diameter, therefore, instead of appearing larger, ought to appear about a sixtieth part less.

1746 *Why are we so often mistaken in respect to the actual distance of a conflagration at night?*

Light radiating from a centre rapidly *weakens* as the distance from the centre *increases*, being, for instance, only one-fourth part as intense at double the distance. The eye learns to make these allowances, and by the clearness and intensity of the light proceeding from the object, judges with considerable accuracy of the comparative distance. But a fire at night appears uncommonly brilliant, and therefore seems near.

1747 *Why does the evening star rising over a hill-top appear as if situated directly over the top of the eminence?*

Because we make brightness and clearness to depend on *contiguity*, as it ordinarily does; and as the star is bright, we unconsciously think it near us.

1748 *What is the cause of colors?*

The *action of light.*

1749 *How is this proved?*

In the dark, bodies have no color, and in the light their colors may be altered by subjecting to certain modifications the light by which they are rendered visible. Thus a *blue* piece of cloth in a *red light* will appear *red.*

1750 *Why is it that we find it difficult to distinguish colors by candle-light?*

Because we have *modified* the light upon which the full effect of the color depends.

1751 *What then is the true definition of color?*

The color of a substance is the *effect of light* on a surface adapted to reflect its particular color.

1752 *Why do some things reflect one color, and some another?*

Because the *surface* of things is so *differently constituted*, both physically and chemically.

1753 *Why is a rose red?*

Because the surface of a rose *absorbs* the *blue* and *yellow* rays of light, and *reflects* only the *red.*

1754 *Why are some things black?*

Because they *absorb all the rays* of light, and reflect *none.*

1755 *Is black a color?*

It is *not;* it is the *absence* of color.

1756 *Why are some things white?*

Because they *absorb none of the rays* of light, but reflect them all.

1757 *Why are clouds, snow, sugar, and salt white?*

Because they *reflect back* unchanged the *white light* which strikes upon them.

1758 *Why are not the crystals of frost and snow transparent like ice?*

The crystals of frost and snow are *not solid*, but they contain air; hence their brilliant whiteness: for the air preventing the ready transmission of light through the crystals, the rays are copiously reflected from the mass of crystals.

1759 *Why is the darkness of night diminished by the presence of snow?*

Because the snow *reflects*, instead of *absorbing*, like the bare ground, the faint light that proceeds from the sky.

1760 *Why are the leaves of plants green?*

Because a peculiar chemical principle, called chlorophyl, is formed within their *cells*, which has the property of absorbing the *red* rays, and of reflecting the blue and yellow, which mixture produces *green.*

1761 *Why are leaves a light green in spring?*

Because the chlorophyl is not fully formed.

1762 *Why do leaves turn brown in autumn?*

Because the chlorophyl undergoes *decay*, and is not replaced as it is in spring.

1763 *Why do all things appear black in the dark?*

In the dark there is no color, because there is no light to be absorbed or reflected, and therefore none to be decomposed.

Of course, in certain degrees of darkness, all objects are actually *invisible.* The question refers to that peculiar degree of darkness when the *forms* of objects may be seen, but not their *hues.*

1764 *Why does the sky appear blue?*

Because the atmosphere *absorbs* the *red* and *yellow* rays, and transmits the *blue.*

1765 *Why does the sun most generally fade artificial colors?*

Generally the loss of color arises from the oxidation of the substances used in dyeing; as tarnish and rust are an oxidation of metals. Sometimes, however, the ingredients of the dye are otherwise decomposed by the sun; and the color (which is due to a *combination* of ingredients) undergoes a change as soon as the sun deranges or destroys that combination.

1766 *What remarkable correspondence is there between the geographical position of a region, and the colors of its plants and animals?*

In the *tropics*, where the sun shines *longest* and *brightest*, the *darkest green* prevails over the leaves of plants, the flowers and fruits are colored *brightly*, and the plumage of the birds is of the *richest* description.

1767 *What is the natural coloration exhibited in temperate climates?*

In temperate climates everything is of a more *sub-*

dued variety; the flowers are *less bright;* the prevailing tint of the birds is *brown;* and the dresses of the inhabitants are sombre.

1768 *How is this correspondence further exemplified in the Arctic and Antarctic regions?*

Here there is *little color* in natural objects; the few flowers are *white* or *yellow;* and the animals are almost uniformly *black* or *white.*

1769 *In what part of the ocean do we find the brightest shells and sea-weeds?*

Near the *shore*, in shallow water, where the influence of *light* is greatest.

1770 *What fishes are distinguished for the brilliancy of their colors?*

Those that *swim* near the *surface;* whereas those which live at greater depths are gray, brown, and black.

1771 *What is the appearance of the sea-weeds and animals that live at great depths of the ocean?*

They are *nearly colorless.*

1772 *Why is grass growing under a covering of a white or yellowish white color?*

Because it is secluded from the *light*, whose presence and action is necessary for the production of the material which imparts to it its green color.

1773 *Of the various rays composing solar light, which are the most visible to the human eye?*

The *yellow.*

1774 *Which have the greatest heating effect?*

The faint *red* rays.

1775 *Why does a dress composed of cloths of different colors, look well much longer, although worn, than one of only a single color, the character of the cloth in both instances being identical?*

It is owing to the effect of *contrast* between the colors. If a dress is composed of cloths of two colors, as red and green, orange and blue, yellow and violet, they will mutually heighten the effect of each, and make each portion appear to the best advantage.

1776 *Why will stains be less visible on a dress of different colors, than on one composed of only a single color?*

Because there exists in general a greater *contrast* among the various parts of the first-named dress, than between the stain and the adjacent part, and this difference renders the stain less apparent to the eye.

1777 *Why can a coat, waistcoat, and pants of the same color be worn with advantage together only when they are new?*

Because as soon as one of them loses its freshness from having been worn longer than the others, the difference will *increase* by *contrast.*

1778 *Give an illustration.*

A pair of new black pants, worn with a vest of the same color, which is old and rusty, will make the tinge of the latter appear more conspicuous, and at the same time the black of the pants will appear more brilliant. White and other light-colored trowsers would produce a contrary effect.

1779 *What is the general law upon which the harmony of colors depends?*

Every color when placed beside another color is *changed*, appearing *different* from what it *really is;* and it moreover equally modifies the color with which it is in proximity.

1780 *What effect has rose-red upon a rosy complexion?*

It causes it to *lose* some of its *freshness.*

1781 *For fair complexions, deficient in rose, which color is most favorable?*

A *delicate green.*

1782 *What effect has black drapery upon the color of the skin?*

It makes it appear *whiter.*

1783 *What rule should be observed in the grouping of flowers and the preparation of bouquets?*

We must separate pink flowers from those that are either scarlet or crimson; orange, from orange yellow flowers; yellow flowers from greenish-yellow flowers; blue from violet-blue, red from orange, pink from violet; blue flowers from violet flowers.

1784 *What is the optical effect of dark colors and black upon the size of the figure?*

It causes it to appear *smaller ;* therefore these colors are most suitable for stout persons.

1785 *What effect do white and light-colored dresses have upon the size of the figure?*

They cause it to appear *larger.*

1786 *What effect do large patterns in dress make?*

They make the figure look *shorter.*

1787 *What is the effect of narrow longitudinal stripes in dress?*

They add to the apparent *height* of the figure.

1788 *What is the effect of horizontal stripes?*

The effect of horizontal stripes is opposed to that of longitudinal, and under every condition they are *ungraceful.*

1789 *What colors are most conspicuous in battle?*

It has been found by numerous observations that *red* is the most fatal color, and the least fatal is a *light grey.*

1790 *What curious provision for the protection of animals does nature appear to make?*

She appears to have adapted the *color* of the creature to its *haunts* in such a way as tends to *preserve* it from *injury.* Caterpillars and insects which feed on leaves are generally of the color of the leaves. As long as they remain still, it is almost impossible to distinguish the grasshopper from the herbage on which it rests.

1791 *What curious change is noticed in the color of animals inhabiting the Arctic regions?*

During the snows of winter, foxes, hares, and some varieties of birds are *white ;* when the ground is free from snow in summer, they are of a *brown* color.

PART VIII.

ELECTRICITY, GALVANISM, MAGNETISM, AND ELECTRO-MAGNETISM.

CHAPTER I.

ELECTRICITY.

1792 *What is electricity?*

Electricity is one of those *imponderable agents* that appear to be diffused through *all nature*, existing in all substances without affecting their volume or their temperature, or giving any indication of its presence when in a latent state. When, however, it is liberated from this repose, it is capable of producing the most *sudden* and *destructive effects*, or of exerting powerful influences by a quiet and long-continued action.

1793 *How may electricity be called into activity?*

By *mechanical power*, by *chemical action*, by *heat*, and by *magnetic influence*.

1794 *What is the most ordinary way of exciting electricity?*

By *friction*.

1795 *Do we know any reason why the means above enumerated should develope electricity from its latent condition?*

We are *entirely ignorant* upon this subject.

1796 *When you rub a piece of paper with India-rubber, why does it adhere to the table?*

Because the *friction* of the India-rubber against the surface of the paper developes *electricity*, to which this adhesiveness is mainly to be attributed.

1797 *Does electricity present any appearance by which it can be known?*

No; electricity, like heat, is in itself *invisible*, though often accompanied by both *light* and *heat*.

1798 *When a substance, by friction or by any other means, acquires the property of attracting other bodies, in what state is it said to be?*

It is said to be *electrified*, or *electrically excited;* and its motion towards other bodies, or of other bodies towards it, is ascribed to a force called electric attraction.

1799 *Does an electrified body exercise any other influence than an attractive one?*

It *does;* for it will be found that light substances, after *touching* the electrified body, will *recede from it* just as actively as they approached it before contact. This is termed *electric repulsion.*

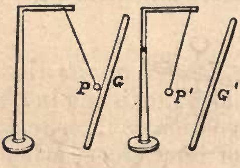


Fig. 81.

Thus, if we take a dry glass rod, rub it well with silk, and present it to a light pith ball, or feather, suspended from a support by a silk thread, the ball or feather will be attracted towards the glass, as seen at G, *Fig.* 81. After it has adhered to it a moment, it will fly off, or be repelled, as P′ from G′. The same will happen if sealing-wax be rubbed with dry flannel, and a like experiment made; but with this remarkable difference, that when the glass repels the ball, the sealing-wax attracts it, and when the wax repels, the glass will attract. These phenomena are examples of *electrical* attraction and repulsion.

1800 *What is a non-electrified body?*

One that holds its own natural quantity of electricity *undisturbed.*

1801 *What happens when an electrified body touches one that is non-electrified?*

The electricity contained in the former is *transferred* in part to the latter.

Thus, on touching the end of a suspended silk-thread with a piece of excited wax, the silk will be excited, as will be shown by its moving towards a book, piece of metal, or any other object placed near it.

1802 *Do all bodies conduct or allow electricity to pass through them equally well?*

Although there is no substance that can *entirely prevent* the passage of electricity, nor any that does not oppose *some resistance* to its passage, yet it moves with a much greater facility through a certain class of substances than through others. Those substances which facilitate its passage are called conductors; those that retard or almost prevent it, are called non-conductors.

1803 *What substances are good conductors of electricity?*

The *metals*, *charcoal*, the *earth*, *water*, and *most fluids*, except oils, the *human body*, etc., are good conductors.

1804 *What substances obstruct the passage of electricity, or are "non-conductors?"*

Glass, *resin*, *oil*, *silk*, *sulphur*, *dry air*, etc., etc., are non-conductors.

1805 *What is an electrical machine?*

An electrical machine is an arrangement by which quantities of electricity can be collected and discharged.

The electrical machine most usually employed consists of a large circular plate of glass, see *Fig.* 82, mounted upon a metallic axis, and supported upon pillars fixed to a secure base, so that the plate can, by means of a handle, *w*, be turned with ease. Upon the supports of the glass, and fixed so as to press easily but uniformly on the plate, are four rubbers, marked *r r r r* in the figure; and flaps of silk, *s s*, oiled on one side, are attached to these, and secured to fixed supports by several silk cords. When the machine is put in motion, these flaps of silk are drawn tightly against the glass, and thus the friction is increased, and electricity excited. The points *p p* collect the electricity from the glass, and convey it to the conductor, *c*, which is supported by the glass rod *g*.

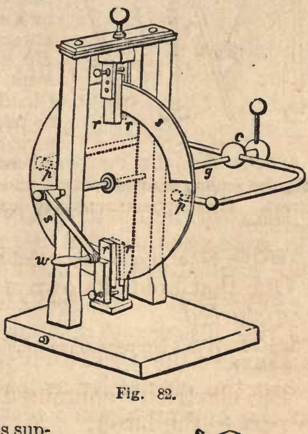


Fig. 82.

Fig. 83 represents another form of an electrical machine, constructed on similar principles. S being a glass cylinder turning on an axis, Y the conductor, F the rubber, A A supports.

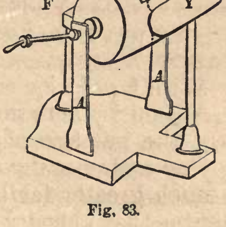


Fig. 83.

1806 *What is the theory of electricity most generally adopted?*

The theory proposed by Dr. Franklin: this supposes the existence of a *single*, *imponderable* *fluid*, equally distributed throughout nature: every substance being so constituted as to retain a certain quantity of this agent. Any disturbance of the natural state of a body produces evidences of electricity.

1807 *Does electricity seem to exist in two different states or conditions?*

It does; and to designate these two conditions, the terms positive and negative have been employed. Thus a body which has an overplus of electricity is called positive, and one that has less than its natural quantity is called negative.

1808 *Do light, heat, and electricity appear to have some properties in common?*

They *do;* each may be made, under certain circumstances, to *produce* or *excite* the other. All are so light, subtle, and diffusive, that it has been found impossible to recognise in them the ordinary characteristics of matter. Some suppose that light, heat, and electricity are all *modifications* of some common principle.

1809 *Why does the fur of a cat sparkle and crackle when rubbed with the hand in cold weather?*

Because the friction between the hand and fur produces an excitation of *negative electricity* in the *hand* and *positive* in the *fur*, and an interchange of the two causes a spark, with a slight noise.

1810 *Why does this experiment work best in very cold weather?*

Because the air is then *very dry*, and does not *convey away* the electricity as fast as it is excited; if the air, on the contrary, were *moist*, the electricity would be *conducted off* nearly as fast as it was excited by friction, and its effects would not therefore be so manifest.

1811 *With what velocity is electricity transmitted through good conductors?*

With a velocity so great that the most rapid motion produced by art appears to be actual rest when compared to it. Some authorities have estimated that electricity will pass through copper wire at the rate of *two hundred and eighty-eight thousand miles in a second* of time—a velocity greater than that of light. The results obtained, however, by the United States Coast Survey, with iron wire, show a velocity of from 15,000 to 20,000 miles per second.

1812 *What agents are undoubtedly the most active in producing and exciting electricity in the operations of nature?*

The *light* and *heat* of the *sun's rays.*

1813 *It has become the habit with many to ascribe to electricity the agency of phenomena in the natural world, the cause of which may not be apparent: is there any reason for this?*

There certainly is not: electricity is *diffused through all matter*, and is ever active, and many of its phenomena cannot be satisfactorily explained; but it is governed, like all other forces of nature, by certain fixed laws, and it is by no means a necessary agent in all the operations of nature.

It argues great ignorance to refer without examination every mysterious phenomenon to the influence of electricity.

1814 *Do some animals have the power of exciting electricity within themselves?*

There *are* certain animals which are *gifted* with the extraordinary power of *producing electrical phenomena* by an effort of muscular or nervous energy. Among these the electrical eel and the torpedo are most remarkable.

1815 *How powerful a charge of electricity can the electrical eel send forth when in full vigor?*

Sufficient to *knock down a man or stun a horse.*

1816 *Is the electricity generated by these animals the same as that occasioned by the ordinary electrical machine?*

It *is the same*, and produces the *same effects.*

1817 *Do vital action and muscular movements in man and animals give rise to electricity?*

They *do;* and it can be shown by direct experiment that a person cannot even *contract the muscles of the arm* without exciting an electrical action.

1818 *Does change of form or state in bodies generally produce electrical excitation?*

Change of form or state is one of the *most powerful methods* of exciting electricity.

Water, in passing into steam by artificial heat, or in evaporating by the action of the sun or wind, generates large quantities of electricity. The crystallization of solids from liquids, all changes of temperature, the growth and decay of vegetables, are also instrumental in producing electrical phenomena.

1819 *What is lightning?*

Lightning is *accumulated electricity*, generally discharged *from the clouds* to the earth, but sometimes from the earth to the clouds.

1820 *What causes the discharge of an electric cloud?*

When a cloud *overcharged* with electric fluid approaches another which is *undercharged*, the fluid rushes from the former *into the latter*, till both contain the *same quantity*.

1821 *Is there any other cause of lightning besides the one just mentioned?*

Yes; sometimes mountains, trees, and steeples will discharge the lightning from a cloud floating near, and sometimes the electricity passes from the earth into the clouds.

1822 *How high are the lightning clouds from the earth?*

Sometimes they are elevated *four or five miles high*, and sometimes actually touch the earth with one of their edges; but they are rarely discharged in a thunder storm when they are more than seven hundred yards above the surface of the earth.

1823 *What is a thunder storm?*

The *disturbance* caused in the *air* when successive discharges of accumulated electricity take place.

1824 *Into how many kinds has lightning been divided?*

Three.

1825 *What are they?*

The *zig-zag lightning*, *sheet lightning*, and *ball lightning*.

1826 *Why is lightning sometimes forked?*

Because the lightning cloud is at a *great distance;* and the *resistance of the air* is so great that the electrical current is diverted into a zig-zag course.

1827 *How does the resistance of the air make the lightning zig-zag?*

As the lightning condenses the air in the immediate advance of its path, it flies from side to side, in order to pass where there is the *least resistance.*

1828 *Why is the flash sometimes quite straight?*

Because the lightning cloud is near the earth, and as the flash meets with very little resistance, it is not diverted; in other words, the flash is straight.

1829 *What is sheet lightning?*

Either the reflection of distant flashes not distinctly visible or beneath the horizon, or else *several flashes intermingled.*

1830 *What other form does lightning occasionally assume?*

Sometimes the flash is *globular*, which is the most dangerous form of lightning.

1831 *Does a discharge produce a flash when it passes through good conductors?*

It *does not*, but passes quietly and invisibly.

1832 *What is heat lightning?*

Sometimes it is the *reflection* in the atmosphere of the lightnings of storms *very remote*, the storms themselves being so far distant that their thunders cannot be heard. This phenomenon is also occasioned by the play of silent flashes of electricity between the earth and the clouds, the amount of electricity developed not being sufficient to produce any other effects than the mere flash of light.

1833 *Why is lightning more common in summer and in autumn than in spring and winter?*

Because the heat of summer and autumn produces *great evaporation*, and the conversion of *water into vapor* always developes *electricity.*

1834 *How long is the duration of a flash of lightning?*

Arago has demonstrated that it does not exceed the *millionth part of a second.*

1835 *With what velocity is lightning, or the electric fluid which gives rise to its appearance, supposed to move?*

Not less than *two hundred and fifty thousand miles per second.*

1836 *Why does lightning sometimes kill men and beasts?*

Because, when the electric current passes through a man or beast, it produces so *violent an action upon the nervous system*, that it destroys life.

1837 *When is a person struck dead by lightning?*

Only when his body forms a part of the *lightning's path;* that is, when the electric fluid (in its way to the earth) actually passes *through his body.*

1838 *What places are most dangerous during a thunder storm?*

It is very dangerous to be *near a tree* or *lofty building.*

1839 *Why is it dangerous to be near a tree or lofty building during a thunder storm?*

Because a tall, pointed object (like a tree or spire) will frequently *discharge* a lightning cloud; and if any one were standing near, the lightning might diverge from the tree and pass through the fluids of the human body.

1840 *How can a tree or spire discharge a lightning cloud?*

A lightning cloud, floating over a *plain*, may be *too far off* to be discharged by it; but as a tree or spire would *shorten* this distance, it might no longer be too far off to be discharged.

For example: If a lightning-cloud were seven hundred yards above the earth, it might be *too far off* to be discharged; but a tree or spire fifty yards high would make the cloud only six hundred and fifty yards off a conductor; in consequence of which the cloud might be instantly *discharged.*

1841 *What parts of a dwelling are most dangerous during a thunder-storm?*

The *fireplace* (especially if the fire be *lighted*). It is also imprudent to sit close by the *walls.*

1842 *Why is it dangerous to sit before a fire during a thunder storm?*

Because the heated air and soot are conductors of lightning, especially when connected with such excellent conductors as the stove, grate, or fire-irons.

1843 *Why is it dangerous to lean against a wall during a thunder storm?*

Because the electric fluid will sometimes *run down a wall*, and (as the body of a person is a better conductor than a wall) would leave the wall and run down the body.

1844 *Why is it dangerous to be in a crowd during a thunder storm?*

For two reasons: 1. Because a *mass of people* forms a better conductor than an individual; and

2. Because the *vapor* arising from a crowd increases its conducting power.

1845 *Why is the danger increased by the vapor which rises from a crowd?*

Because *vapor* is a conductor, and the more *conductors* there are, the greater the danger will be.

1846 *If a person be abroad in a thunder storm, what place is the safest?*

Any place about twenty or thirty feet from a *tall tree*, building, or stream of water.

1847 *Why would it be safe to stand twenty or thirty feet from a tall tree during a thunder storm?*

Because the lightning generally chooses tall trees as conductors, and we should not be sufficiently near the trees for the lightning to diverge from *them* to *us*.

1848 *Why is the middle of a room more safe than any other part of it in a thunder storm?*

Because the lightning (if it should strike the room at all) would come down the chimney or walls of the room; and therefore the farther distant from these, the better.

1849 *Why is a mattress, bed, or hearth-rug a good security against injury from lightning?*

Because they are all non-conductors; and as lightning always makes choice of the *best* conductors, it would not choose for its path such things as these.

1850 *What is the safest thing a person can do to avoid injury from lightning?*

Lie upon a *bed* in the *middle* of a room. A *bed* filled with *feathers* is an excellent *non-conductor*.

1851 *Is there not generally a greater apprehension of the danger from lightning than experience would justify?*

The apprehension and solicitude respecting lightning are proportionate to the magnitude of the evils it produces, rather than the frequency of its occurrence. The chances of an individual being killed by lightning are *infinitely less* than those which he encounters in his *daily walks*, in his *occupation*, or even during his *sleep* from the destruction of the house in which he lodges by fire.

1852 *Why does the lightning in its course down a building generally dart from point to point, and not follow a direct path?*

Because it always takes in its course the *best conductors;* and will fly both right and left in order to reach them.

1853 *What is a lightning conductor?*

A *metal rod* fixed in the earth, running up the whole height of a building, and rising in a point above it.

1854 *What metal is best for this purpose?*

Copper makes the best conductor.

1855 *What is the use of a lightning conductor?*

As metal is a most excellent conductor, lightning (which makes choice of the *best conductors*) will run down a *metal rod* rather than the walls of the building.

1856 *Why should lightning conductors be pointed?*

Because points conduct electricity away *silently* and *imperceptibly*.

Blades of grass, ears of corn, and other pointed objects serve to withdraw electricity from the clouds.

1857 *How far will the beneficial influence of a lightning conductor extend?*

It will protect a space all round four times the length of that part of the rod which *rises above the building.*

1858 *Give me an example.*

If the rod rises *two feet* above the house, it will protect the building for (at least) *eight feet* all round.

1859 *How can lightning conductors be productive of harm?*

If the rod be *broken*, the electric fluid (being obstructed in its path) will enter the building.

1860 *Is there any other evil to be apprehended from a lightning rod?*

Yes; if the rod be not large enough to conduct the *whole* current to the earth, the lightning will *fuse* the metal and enter the building.

1861 *By whom was the identity of lightning and electricity first established?*

By *Dr. Franklin*, at Philadelphia, in 1752.

The manner in which this fact was demonstrated, was as follows: Having made a kite of a large silk handkerchief stretched upon a frame, and placed upon it a pointed iron wire connected with the string, he raised it upon the approach of a thunder storm. A key was attached to the lower end of the hempen string holding the kite, and to this one end of a silk ribbon was tied, the other end being fastened to a post. The kite was now insulated, and the experimenter for a considerable time awaited the result with great solicitude. Finally, indications of electricity began to appear on the string; and on Franklin presenting his knuckles to the key, he raised an electric spark. The rain beginning to descend, wet the string, increased its conducting power, and vivid sparks in great abundance flashed from the key.

1862 *Why was the kite insulated when Franklin fastened the key to the post with a silk ribbon?*

Because the silk was a *non-conductor*, and would not allow the electricity received upon the kite to pass off by means of the string to the ground.

1863 *Was this experiment one of great danger and risk?*

It was; because the whole amount of electricity contained in the thunder cloud was *liable to pass from* it, by means of the string, to the earth, notwithstanding the use of the silk insulator.

1864 *If a lightning rod is made of iron, how large should it be?*

Not less than *three-quarters of an inch* in diameter.

1865 *In what manner should the rod be erected?*

The rod should be continuous from the *top to the bottom*, and an entire metallic communication should exist throughout its whole length.

This law is violated when the joints of the several parts that form the conductor are imperfect and when the whole is loosely put together.

1866 *How should the conductor be fastened to the building?*

By *wooden supports*.

If there are masses of metal about the building, as gutters, pipes, etc., these should be connected with the rod by strips of metal; for unless this is done the lightning may pass from the rod to the metal, and enter the building.

1867 *How should the lower end of the rod be arranged?*

It should be *divided* into *two or three branches*, and turned from the building.

The end of the rod ought to extend so far below the surface of the ground as to reach earth that is permanently damp.

1868 *Why is it a good plan to bury the end of the rod in powdered charcoal?*

Because it preserves the iron from *rust*, and *facilitates* the *passage* of the electricity.

1869 *Have we any proof of the utility of lightning rods?*

The experience of a hundred years has shown that when all the *necessary rules* have been *observed*, the protection is perfect, as far as human effort can avail.

1870 *Is a building more or less liable to be struck when furnished with a good lightning conductor?*

Lightning conductors do *not*, as many suppose, *attract the lightning towards the building* on which they are situated; they simply *direct its course*, and *facilitate* the *passage* of the *fluid* in the most direct way to the earth, only when a discharge must inevitably occur. There is no attraction, but the lightning takes the road which offers the least resistance.

1871 *Are lightning conductors protective when even no visible discharge takes place?*

They *are;* they possess a very great *preventive power*, and gradually and silently disarm the clouds by conducting the electricity from them; and this process commences as soon as the cloud has approached a position vertically over the rod.

1872 *What is thunder?*

It is a certain *noise* proceeding apparently from the clouds, which usually follows, after a greater or less interval, the appearance of a flash of lightning.

1873 *How is it supposed to be occasioned?*

The usual explanation offered is a *sudden displacement of the air* produced by the electrical discharges in which the lightning is evolved.

Others have supposed that the passage of the electric current creates a vacuum, and that the air rushing in to fill it produces the sound. Any explanation that has yet been offered is not altogether satisfactory.

1874 *What occasions the rolling of the thunder?*

It has been ascribed to the *effect of echo;* but the true cause probably is, that the sound is developed by the lightning in passing through the air, and consequently separate sounds are produced at every point through which the lightning passes.

1875 *Why is thunder sometimes one vast crash?*

Because the lightning cloud is *near the earth;* and as all the vibrations of the air (on which sound depends) reach the ear at *the same moment*, they seem like one vast sound.

1876 *Why is the thunder generally heard several moments after the flash?*

Because it has a *long distance* to travel. Lightning travels nearly *a million* times faster than thunder; if, therefore, the thunder has *a great distance to come*, it will not reach the earth till a considerable time *after the flash.*

1877 *Can we not tell the distance of a thunder cloud by observing the interval which elapses between the flash and the peal?*

Yes; the flash is instantaneous, but the thunder will take a whole *second of time* to travel three hundred and eighty yards; hence, if the flash be five seconds before thunder, the cloud is nineteen hundred yards off.

i. e. $380 \times 5 = 1900$ yards.

1878 *What is the aurora borealis or northern lights?*

Luminous appearances seen in the *sky* at night-time. Sometimes streaks of blue, purple, green, red, etc., and sometimes flashes of light, are seen.

1879 *What is the cause of the aurora borealis or northern lights?*

Electricity in the higher regions of the atmosphere is undoubtedly an active agent in producing this phenomenon.

1880 *Is the aurora ever seen in other parts of the heavens than towards the north?*

In the northern hemisphere it always appears in the *north*, but in the southern hemisphere it appears in the *south:* it seems to originate at or near the *poles of the earth*, and is consequently seen in its greatest perfection within the arctic and antarctic circles.

1881 *What is known concerning the extent of the aurora?*

It is not *local*, but it is seen simultaneously at places widely remote from each other, as in Europe and America.

1882 *What calculations have been made respecting the height of the aurora?*

The height of the appearances varies from *one to two hundred miles;* they sometimes appear within the region of the clouds, and very near to the earth.

1883 *Do the auroras appear at any particular seasons and times?*

They appear more frequently in the *winter* than in the summer, and are only seen at *night.*

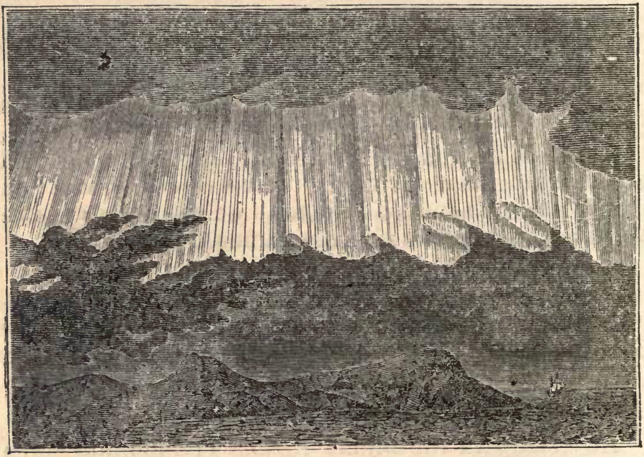


Fig. 84.

The accompanying figure represents one of the most beautiful of the auroral phenomena.

1884 *Do they also occur in the day-time?*

The aurora is known to *affect the magnetic needle* and the telegraph; and as the effects upon these instruments are noticed by day as well as by night, there can be no doubt of the occurrence of the aurora at all hours. The intense light of the sun renders the auroral light invisible during the day.

1885 *Of what utility are the auroral appearances in the polar regions?*

During the long polar night, when the sun is absent, the aurora appears with a magnificence unknown in other regions, and affords *light sufficient* for many of the *ordinary out-door employments.*

CHAPTER II.

GALVANISM.

1886 *What is galvanism?*

It is the production of *electrical disturbance by chemical action.*

1887 *What is the most simple manner of illustrating the production of this electricity?*

If we place a piece of silver on the tongue, and a piece of zinc underneath it, no effect will be produced as long as the two metals are kept asunder; but when their ends are brought together, a *distinct thrill* will pass through the tongue, a metallic taste will diffuse itself, and, if the eyes are closed, a sensation of *light* will be evident at the same moment.

1888 *To what is this result owing?*

To a *chemical action* developed the moment the two metals touched each other.

The *saliva* of the tongue *oxidizes* a portion of the *zinc*, which excites *electricity*, for no chemical action ever takes place without producing electricity. Upon bringing the ends of the two metals together, a slight current passes from one to the other.

1889 *By whom was the production of galvanic electricity first noticed?*

By *Galvani*, professor of anatomy at Bologna, Italy, in 1790.

Having occasion to dissect several frogs, he hung up their hind legs on some *copper hooks*, until he might find it necessary to use them for illustration. In this manner he happened to suspend a number of the copper hooks on an iron balcony, when, to his great astonishment, the limbs were thrown into violent convulsions.

1890 *On investigating the phenomena what did Galvani discover?*

He found that whenever the nerves of a frog's leg were touched by one metal and the muscles by another, convulsions took place on bringing the two different metals in contact.

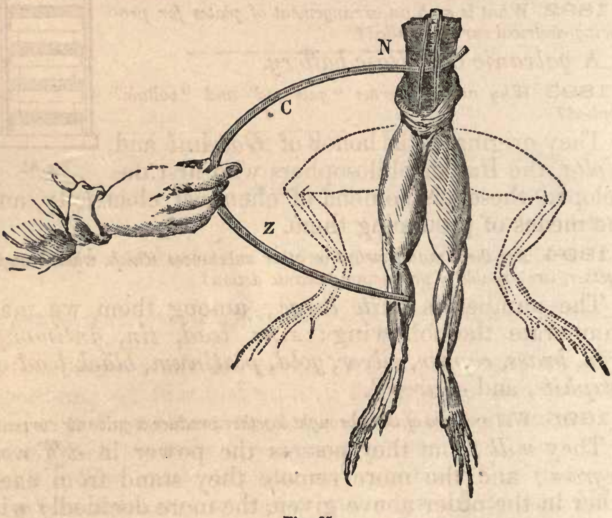


Fig. 85.

This is explained by reference to *Fig.* 85, which represents a frog's legs, the upper part dissected in such a way as to exhibit the nerves of the legs, and a portion of the spinal marrow. If we now take two thin pieces of copper and zinc, C Z, and place one under the nerves, and the other in contact with the muscles of the leg, we shall find that so long as the two pieces of metal are separated, so long will the limbs remain motionless, but by making a connection, instantly the whole lower extremities will be thrown into violent convulsions, quivering and stretching themselves in a manner too singular to describe. If the wire is kept closely in contact, these phenomena are of momentary duration, but are renewed every time the contact is made and broken. Here, then, we have distinct evidence of the presence of free electricity, developed apparently by simple contact.

1891 *What is the simplest way of exciting a current of galvanic electricity?*

By arranging a *series of metal plates in a pile*, placing them in pairs, with a wet cloth between them, it being necessary that one of each pair should be more easily oxidized than the other. The simple contact of these plates will produce a feeble and continued galvanic current.

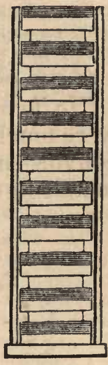


Fig. 86.

Fig. 86 represents an arrangement of this character.

1892 *What is such an arrangement of plates for producing electrical currents called?*

A *galvanic* or *voltaic battery.*

1893 *Why are the terms "galvanic" and "voltaic" applied?*

They originated in honor of *Galvani* and *Volta*, the Italian philosophers who first developed these phenomena of chemical electricity, and the means of producing them.

1894 *Are there many metals or other substances which, when brought together, are capable of producing galvanic action?*

The number is *quite large;* among them we may enumerate the following: *zinc*, *lead*, *tin*, *antimony*, *iron*, *brass*, *copper*, *silver*, *gold*, *platinum*, *black lead* or *graphite*, and *charcoal.*

1895 *Will any two of these brought together produce a galvanic current?*

They *will;* but they possess the power in *different degrees;* and the more remote they stand from each other in the order above given, the more decidedly will the chemical electricity be developed.

Thus zinc and lead will produce a voltaic battery, but it will be much less active than zinc and iron, or the same metal and copper, and this last less active than zinc and platinum, or zinc and charcoal.

1896 *Does galvanic or voltaic electricity appear to consist of two kinds, positive and negative, as in ordinary electricity?*

It does; positive electricity always flows *from the metal which is acted upon* most powerfully, and negative electricity *from the other.*

1897 *What do we mean when we speak of a galvanic circuit?*

The connection of the two metals in the battery, so that the positive and negative electricities can *meet, and flow in opposite directions.*

1898 *At what point in the circuit will the manifestations of electricity be most apparent?*

At the point where the *two currents meet.*

1899 *What is meant by the poles of the battery?*

The two metals forming the elements of the battery are generally connected by copper wires; the *ends* of these wires, or the *terminal points* of any other connecting medium used, are called the poles of the battery.

Thus, when zinc and copper poles are used, the end of the wire conveying positive electricity from the zinc would be the positive pole, and the end of the wire conveying negative electricity from the copper plate would be the negative pole. Faraday describes the poles of the battery as the doors by which electricity enters into or passes out of the substance suffering decomposition.

A very simple, and at the same time an active, galvanic circuit may be formed by an arrangement as represented in *Fig.* 87. C and Z are thin plates of copper and zinc immersed in a glass vessel containing a very weak solution of sulphuric acid and water. Metallic contact is made by means of the wires, X and W, soldered to the plates, the poles intersecting at Y. The current of positive electricity, when the circuit is closed, passes from the zinc, through the liquid, to the copper, and from the copper, along the conducting wires, to the zinc, as indicated by the arrows in the figure. A current of negative electricity traverses the circuit also, from the copper to the zinc, in a direction precisely reversed.

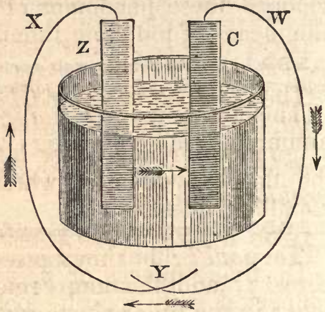


Fig. 87.

1900 *By what chemical action can the greatest abundance of galvanic electricity be developed?*

By the *oxidation of metallic zinc* by weak sulphuric acid.

1901 *The electricity developed by the action of a single pair of plates immersed in acid water is very feeble: how can it be increased?*

By increasing the *number of the plates* and the quantity of the liquid, we increase the intensity of the electricity developed.

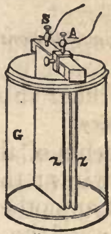


Fig. 88.

Fig. 89.

Figs. 88 and 89 represent some of the most common forms of galvanic batteries. In *Fig.* 88 two plates of zinc, *z z*, inclosing a piece of silver between them, are immersed in a glass cylinder, G, containing acid; S and A represent the poles of the battery. In *Fig.* 89 the battery consists of two concentric cups or cylinders of copper, C, and a cylinder of zinc, Z, fitting between. The acid solution is poured into the spaces between the cylinders. Another form consists of an earthenware trough, containing acid, in which alternate plates of copper and zinc are arranged, and connected together by wires rising from each end of the trough.

1902 *What are the most ordinary effects produced by the developed electricity of a large galvanic battery?*

The *production of sparks* and *brilliant flashes of light*, the heating and fusing of metals, the deflagration of gunpowder and other inflammable substances, and the decomposition of water, saline compounds, and metallic oxides.

1903 *How may the most splendid artificial light known be produced?*

By fixing pieces of *pointed charcoal* to the wires connected with opposite poles of a powerful galvanic battery, and bringing them into *contact.*

1904 *Can intense heat be developed by the action of the galvanic battery as well as intense light?*

The *greatest artificial heat* man has yet succeeded in producing has been through the agency of the *galvanic battery.*

1905 *What refractory substances can be fused by the aid of the galvanic battery?*

All the metals, including platinum, can be *readily* *melted;* quartz, sulphur, magnesia, slate, and lime are liquefied; and the diamond fuses, boils, and becomes converted into coal.

1906 *What is electrotyping, or electro-metallurgy?*

It is the art or process of *depositing*, from a *metallic solution*, through the agency of galvanic electricity, a *coating* or *film* of metal upon some other substance.

1907 *Upon what principles is it accomplished?*

The process is based on the fact, that when a galvanic current is passed through a solution of some metal, as a solution of sulphate of copper (sulphuric acid and copper), *decomposition takes place;* the metal is separated in a metallic state, and attaches itself to the negative pole, or to any substance that may be attached to the negative pole; while the acid or other substance before in combination with the metal, goes to, and is deposited on the positive pole.

In this way a medal, a wood-engraving, or a plaster cast, if attached to the negative pole, may be covered with a coating of copper; if the solution had been one containing silver or gold, the substance would have been covered with a coating of silver or gold instead of copper.

1908 *How can the thickness of the deposits be regulated?*

The thickness of the deposit, providing the supply of the metallic solution be kept constant, will depend on the *length of time the object is exposed to the influence of the battery.*

In this way, a coating of gold thinner than the thinnest gold-leaf can be laid on, or it may be made several inches or feet in thickness, if desired.

The process of electrotyping has been strikingly taken advantage of in reproducing expensive engraved plates, as the map-plates of the Coast Survey of the United States. The plate of the map, usually on copper, is frequently the work of years under the hand of the engraver, the cost being counted by thousands of dollars. If the plate, when finished, were *printed on directly*, the pressure of the paper a few hundred times would soon *obliterate* the *faint lines* of the engraving on the metal, and the plate would soon become injured or spoiled. But now the *original plate* is never printed on, but an electrotype on copper is taken from it, at a very small expense; and this may be repeated almost indefinitely, thus affording fresh plates for printing whenever required.

CHAPTER III

MAGNETISM.

1909 *Is there any connection between magnetism and electricity?*

There is every reason to believe that magnetism and electricity are but *modifications of one force.*

1910 *What is a loadstone or a natural magnet?*

It is an *ore of iron*, known as the "*protoxide of iron*," or "*magnetic oxide of iron*," which is capable of attracting other pieces of iron to itself; and if suspended freely by a thread, and left to take its own position, it will arrange itself so that its extremities will point towards the north and south poles of the earth.

1911 *Are natural magnets rare?*

They are *not;* they are found in many places in the *United States.* In *Arkansas*, especially, an ore of iron possessing remarkably strong attractive powers is very abundant.

The magnetic ore is usually of a dark grey hue, and possesses but little metallic lustre. *Fig.* 91. If a piece of this ore be dipped in iron filings, or a number of small needles, they will generally be found collected and clinging together in great quantities at two opposite extremities, as represented in the figure, whilst the middle portion is nearly destitute. The magnetic property, whatever it may be, seems therefore to be collected and act with the greatest energy at two opposite extremes; these have been termed *poles.*

Fig. 91.

1912 *What is the origin of the terms "magnet" aud "magnetism?"*

The loadstone or natural magnet was first found at *Magnesia*, in Lydia, Asia, whence were derived the names.

1913 *Can a natural magnet communicate its attractive properties to other bodies by contact?*

It *can*, and that too without any *apparent loss* of attractive strength.

1914 *What bodies are capable of being magnetized by contact with natural magnets?*

Iron and *steel* are the substances most susceptible of this influence, but brass, nickel, and cobalt can also become magnets.

1915 *Does the magnetism imparted to a piece of soft iron, or steel, by contact with a natural magnet, remain permanent in their substances?*

In the *steel* it *does*; but the soft iron *loses its power* as soon as it is removed from the magnet.

1916 *Is it necessary that absolute contact should take place between a magnet and a piece of soft iron to render the latter a magnet?*

No, every piece of soft iron brought *near* a magnet becomes by induction itself a magnet.

1917 *What do you mean by induction?*

It is the production of *like effects* in *contiguous bodies*. In electricity or magnetism, it is the influence exerted by an electrified or magnetized body through a non-conducting medium without any apparent communication of a current.

1918 *What is meant by the directive power of the magnet?*

It is that power which will cause a magnet, when suspended freely, to constantly *turn the same part* towards the north pole and the opposite part towards the south pole of the earth.

1919 *What are the poles of a magnet?*

They are the *ends* of the magnet, and are denominated north and south poles, according as they point to the north or south poles of the earth.

1920 *What are the poles of the earth?*

The *extremities of the earth's axis*, or the points on the surface of the globe through which the axis passes.

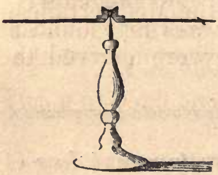


Fig. 92.

1921 *What is a magnetic needle?*

Simply a *bar of steel* which is a *magnet*, suspended in such a way that it can *freely turn* to the north or south.

1922 *What is a mariner's compass?*

It is a *delicate steel bar or*

needle balanced upon a *pivot* placed beneath its centre of gravity in such a way that it can turn horizontally without obstruction. This needle is usually inclosed in a box, upon the bottom of which is a card, with the various points—north, south, east, west, etc., etc., marked upon it.

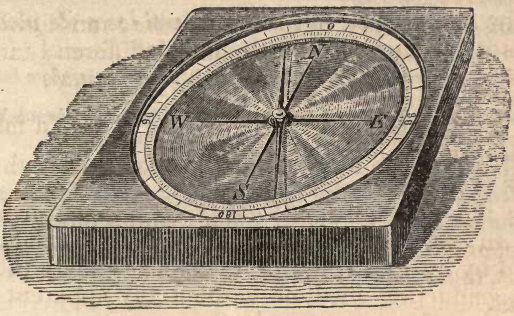


Fig. 92.

Such a needle, if the box containing it be placed on a level surface, will generally be observed to vibrate more or less, till it settles in such a direction that one of its extremities or poles will point towards the north, and the other consequently towards the south. If the position of the box be altered or reversed, the needle will always turn and vibrate again, till its poles have attained the same direction as before.

1923 *Does the compass needle always point exactly north and south?*

It does *not;* its natural direction is towards the north and south poles, but it seldom points due north or south.

1924 *Who first discovered the fact that a magnet would invariably point to the north and the south, and made use of this knowledge in constructing a compass?*

It is claimed to have been discovered by the *Chinese:* it was known in Europe, and used in the Mediterranean, in the thirteenth century.

1925 *How were the compasses of that time constructed?*

They were merely *pieces of loadstone* fixed to a *cork,* which floated on the surface of water.

1926 *Is the earth itself supposed to be a magnet?*

It is undoubtedly a *great magnet.*

1927 *Is iron under certain circumstances rendered magnetic by the inductive action of the earth's magnetism?*

Most *iron bars* and *rails*, as the vertical bars of windows, that have stood for a considerable time in a perpendicular position, will be found to be *magnetic.*

1928 *If we suspend a bar of soft iron sufficiently long in the air, will it assume magnetic properties?*

It *will* gradually *become magnetic;* and although when it is first suspended it points indifferently in any direction, it will at last point *north and south.*

1929 *How may a bar of iron, such as a kitchen poker, be made immediately magnetic, without resorting to the use of other magnets?*

If the bar devoid of magnetism is placed with *one end on the ground*, slightly inclined towards the north, and then struck one *smart blow* with a *hammer* upon the upper end, it will immediately acquire *polarity*, and exhibit the attractive and repellant properties of a magnet.

1930 *What is a horse-shoe magnet?*

It is a *magnetic bar* bent into the *form of a horse-shoe.*

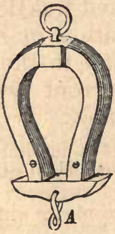


Fig. 93.

When a piece of iron not magnetic is brought in contact with a common magnet, it will be attracted by either pole; but the most powerful attraction takes place when both poles can be applied to the surface of the piece of iron at once. The magnetic bars are for this purpose bent into the shape of the letter U, and are termed *horse-shoe magnets.* Several of these are frequently joined together with their similar poles in contact; they then constitute a *magnetic battery*, and are very powerful, either for lifting weights, or charging other magnets. (See *Fig.* 93.)

1931 *If we break a magnet across the middle, what happens?*

Each fragment becomes converted into a *perfect magnet;* the part which originally had a north pole acquires a south pole at the fractured end, and the part which originally had a south pole, gets a north pole.

1932 *If we divide up a magnet to the extreme degree of mechanical fineness possible, will the pieces possess magnetic powers?*

Each fragment, however small, will be a *perfect magnet.*

CHAPTER IV.

ELECTRO-MAGNETISM.

1933 *What is electro-magnetism?*

It is the magnetism developed through the agency of *electrical* or *galvanic action.*

1934 *What were the earliest phenomena observed which indicated a relation between magnetism and electricity?*

It was noticed that *ship's compasses* have their directive power impaired by lightning, and that sewing needles could be rendered magnetic by electric discharges passed through them.

1935 *What discovery, made by Prof. Oersted of Copenhagen, established beyond a doubt the connection of electricity and magnetism?*

He ascertained that a magnetic needle placed near a metallic wire connecting the poles of a galvanic battery was compelled to change its direction, and that the new direction it assumed was determined by its position in *relation to the wire* and to the direction of the current *transmitted along the wire.*

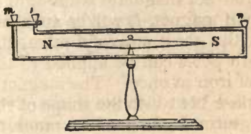


Fig. 94.

Thus, if, as in *Fig.* 94, a needle be inclosed in a wire not touching it at any point, and a current of electricity pass through the wire, the needle will be made to move in accordance with the direction of the current.

1936 *What other important discovery was made about the same time?*

It was found that if a piece of soft iron, not possessing magnetic power sufficient to elevate a grain weight, be placed within a coil of copper wire through which a galvanic current is passing, it will become, through the influence of the current, a *powerful magnet;* and will, so long as the current flows, sustain weights amounting to many hundreds of pounds. (See *Figs.* 95 and 96.)

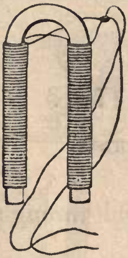


Fig. 94.

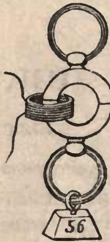


Fig. 95.

1937 *Is the magnetic power of the bar found to be wholly dependent on the existence of the current?*

It *is;* the moment the current stops, the weights *fall away* from the bar in obedience to the law of gravity.

1938 *How great weights have been lifted by magnets formed in this manner?*

An electro-magnet constructed by Prof. Henry was capable of elevating and sustaining about a *ton weight.*

1939 *Upon what principle does the construction of the Morse magnetic telegraph depend?*

Upon the principle that a current of *electricity* circulating about a bar of soft iron is capable of *rendering it a magnet.*

The arrangement by which this principle is made available in the construction and operation of the Morse magnetic telegraph will be understood by reference to the accompanying diagram (*Fig.* 96), which represents the construction and arrangement of this form of telegraph. F and E are pieces of soft iron surrounded by coils of wire, which are connected at *a* and *b* with wires proceeding from a galvanic battery. When a current is transmitted from a battery located one, two, or three hundred miles, as the case may be, it passes along the wires and into the coils surrounding the pieces of soft iron F and E, thereby converting them into magnets. Above these pieces of soft iron is a metallic bar or lever, A, supported on its centre, and having at one end the arm D, and at the other a small steel point, *o*. A ribbon of paper, *p h*, rolled on the cylinder B, is drawn slowly and steadily off by a train of clock-work, K, moved by the action of the weight P on the cord C. This clock-work gives motion to two metal rollers, G and H, between which the ribbon of paper passes, and which, turning in opposite directions, draw the paper from the cylinder B. The roller H has a groove around its circumference (not represented in the engraving) above which the paper passes. The steel point, *o*, of the lever, A, is also directly opposite this groove. The spring *r* pro-

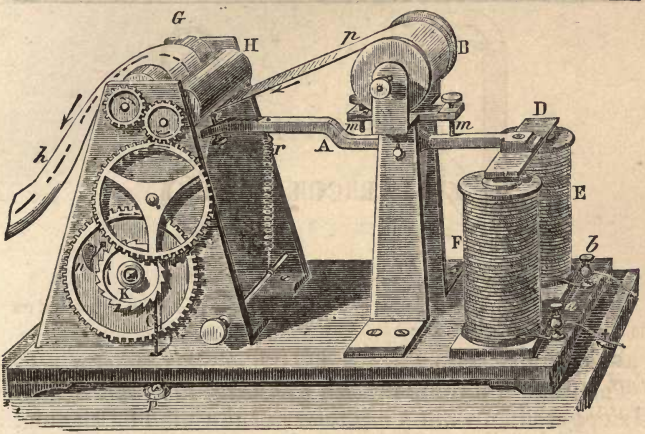


Fig. 96.

vents the point from resting upon the paper when the telegraph is not in operation.

1940 *Why is it necessary, in conveying the telegraph wires, to support them upon glass or earthen cylinders?*

These are used for the purpose of insuring the perfect *insulation* of the wires, since but for this the electricity would pass down a damp pole to the earth, and be lost.

1941 *Is there any truth in the idea that many persons have, that some principle passes along the telegraphic wires when intelligence is transmitted?*

This supposition is *wholly erroneous;* the word current, as something flowing, conveys a false idea, but we have no other term to express electrical progression.

1942 *How can we gain an idea of what really takes place, and of the nature of the influence transmitted?*

The earth and all matter are *reservoirs of electricity;* if we disturb this electricity at Boston by voltaic influence, its pulsations may be felt in New York. Suppose the telegraphic wire were a tube, extending from Boston to New York, filled with water. Now, if one drop more is forced into it at Boston, a drop must fall out at New York, but no drop was caused to pass from Boston to New York. Something similar to this occurs in the transmission of electricity.

PART IX.

FAMILIAR CHEMISTRY.

1943 *What is starch?*

The name starch is given to a *mealy substance* which is deposited in *most vegetables* at the time of ripening, from the juices with which the cells of the plants are filled.

1944 *What common vegetable especially abounds in starch?*

The *potato;* which consists entirely of cells filled with starch and water.

A cell is a little membranous bladder filled with a solid or fluid substance.

1945 *Why does the laundress find it necessary to boil starch before using it for stiffening linen, etc.?*

The starch, consisting of little granules, is *insoluble in cold water;* but when acted upon by hot water, the granules burst and allow their contents, which are soluble, to become mingled with the water.

Starch is manufactured as follows:—

Potatoes, for example, from which most of the starch of commerce is manufactured, after being pared, are grated to a pulp. This pulp is put upon a sieve and stirred about, while at the same time a little stream of water is made to flow upon it. A milky liquid runs through the sieve, but the fibrous portion of the potato, the vegetable tissue, remains behind. This liquid, after a short interval, deposits a white powder, which is the starch. By the simple process of tearing up the vegetable tissue, and removing the inclosed starch by washing, this substance may be procured from a great variety of plants.

1946 *Why do potatoes, beans, rice, and most of the common vegetables, swell up when boiled with water?*

Because the *starch absorbs water* at the boiling temperature, which causes the *cells to swell*, thereby giving to the vegetable a rounded appearance.

1947 *What is the composition of wheat flour?*

Starch is one of the *principal constituents* of wheat flour, as well as of all other kinds of meal. The other principal constituent is a grey, tough, viscous substance, called *gluten.*

1948 *To what does paste, made of wheat or rye flour, owe its adhesiveness?*

In some measure to the *starch*, but principally to the *gluten* contained in it.

1949 *Can starch be converted into gum and sugar?*

It *can; fruits and plants effect this change naturally:* we can also produce the change artificially by chemical processes.

1950 *Why are potatoes frozen and thawed sweet?*

Because by the *freezing action* the starch of the potato is in part *converted into sugar.*

1951 *Why are apples, pears, grapes, etc., in their unripe state sour, and in their ripe condition sweet?*

In the unripe fruits mentioned *starch is present;* in the ripe fruits it is *absent;* in the process of ripening the starch is *converted into sugar*, and the fruit losing its sour taste, becomes sweet.

1952 *What are acids?*

Acids are substances which excite the *taste of sourness* when applied to the tongue; they change the *blue juices* of vegetables to *red*, and combine with alkalies to form neutral compounds.

1953 *What is an alkali?*

An *alkali* is a body that possesses properties the *converse of those of an acid.* It has a *highly bitter, acrid taste*, changes the *blue juices* of vegetables *green*, or the juices of vegetables which have been changed red by an acid, back again to blue. Potash and soda are the representatives of the alkalies.

1954 *When sulphur is burned in the air what is the product formed?*

Sulphurous acid.

1955 *What causes the suffocating odor of a lighted brimstone match?*

The *sulphurous acid* generated by the combustion of the sulphur.

1956 *What is sulphuric acid or oil of vitriol?*

It is a compound of *sulphur and oxygen*, containing one-third more oxygen than sulphurous acid.

1957 *What is sulphuretted hydrogen?*

A *gas* formed by the union of *sulphur and hydrogen*. It possesses an offensive odor, and is very poisonous.

1958 *How is sulphuretted hydrogen formed in nature?*

Principally from the *decomposition of animal substances*, as blood, flesh, hair, etc.

1959 *Why does the yolk of an egg tarnish a silver spoon?*

Because it contains a *little sulphur*, which, at the temperature of an egg just boiled, will decompose the water or moisture upon the spoon, and produce *sulphuretted hydrogen gas*, which will tarnish silver.

Both the white and the yolk contain sulphur, but the latter the most abundantly.

1960 *What is it that makes an open or foul sewer so destructive of health to any district in which it may be situated?*

The evolution of *sulphuretted hydrogen*. When inhaled, it acts directly upon the blood, thickening it, and turning it black.

1961 *Why do surfaces painted with lead paints, in the vicinity of sewers, soon turn black, or become discolored?*

Through the action of *sulphuretted hydrogen*.

1962 *What is nitric acid?*

Nitric acid, or aqua-fortis, is a compound of five parts of oxygen and one of nitrogen.

It is a *liquid;* when pure, *colorless*, and highly *corrosive;* it attacks almost all dead, unorganized substances, and destroys living tissues.

1963 *What is muriatic, or, more properly, hydrochloric acid?*

A compound of *hydrogen and chlorine* usually prepared from salt. It is an acid much used in the arts.

1964 *What is "lunar caustic?"*

A compound of *nitric acid* and *oxide of silver*.

1965 *Why, when lunar caustic is applied to the flesh, does it burn and destroy it?*

Through the agency of the *nitric acid* contained in it.

1966 *Do plants produce acids?*

Acids are formed in the *vegetable kingdom* in *great abundance;* they especially exist in unripe fruits, imparting to them a sour taste.

Acids formed from mineral substances are called "mineral acids;" acids formed by or from vegetable substances are called "organic acids."

1967 *Why does tanning hides convert them into leather?*

Hides are steeped in water, with ground bark of the oak, hemlock, or other trees; these barks contain large quantities of *tannic acid*, which combines with the skin of animals, and forms a combination which is insoluble in water and not subject to putrefaction—viz. leather.

1968 *What is ordinary vinegar?*

An *acid*, called *acetic acid*, and water.

1969 *If wine or beer be imperfectly corked, why does it rapidly turn sour?*

Because air gets into the liquor, and the oxygen of the air combining with the alcohol of the liquor produces acetic acid, or *vinegar*.

1970 *What is alcohol?*

Alcohol is the *spirit* existing in wine, beer, cider, etc., *obtained in the process of fermentation.*

1971 *What is a ferment?*

A ferment is a substance containing *nitrogen* in a state of *decomposition*, which is able to excite fermentation in solutions of sugar; old cheese, putrefying flesh, blood, etc., all of them are ferments.

1972 *What is yeast?*

We apply the term yeast to a particular species of ferment; the *foam of beer* (or of some similar liquor), produced by *fermentation.*

1973 *Can you explain why it is that a body in a state of fermentation or putrefaction should cause unlimited quantities of similar matter to pass into the same state?*

We only *know the fact:* the reason we are *ignorant of.* The most minute portion of milk, paste, juice of grapes, flesh, or blood, in a state of fermentation or putrefaction, causes fresh milk, paste, grape juice, flesh, or blood, to pass into the same condition, when in contact with them.

1974 *In storing or packing fruit for future use why is it necessary to carefully remove every decayed specimen?*

Because the decayed portions of one specimen will quickly *communicate decay to the fresh fruit in contact* with it, and soon the whole mass of fruit will become putrescent.

1975 *If in a vessel, or any other structure, one timber becomes decayed what course ought to be adopted?*

It should be removed *immediately*, or the decomposition once commenced will in time affect the whole structure.

It sometimes happens that physicians, in dissection, are seriously poisoned by the slightest cut of a knife which has been used upon the dead body. The knife introduces to the healthy blood, through the wound, a *minute portion of matter in the state of decomposition or putrefaction.* This acts as a *ferment*, and causes the healthy matter in contact with it to pass into the same decomposed state. The action once commenced rapidly extends, until the whole body becomes affected, and death ensues. It is almost impossible to heal wounds of this character.

1976 *Why is it especially dangerous to eat fruit or meats partially decayed?*

Because the *decayed portions* of the substance eaten are liable to induce the *same condition* in the healthy organs of the stomach with which they may come in contact.

1977 *Why do fruit preserves frequently turn sour?*

Because, owing to the action of some fermenting substance present either in the fruits themselves or in the air, the sugar used in preserving is *converted into alcohol*, and the alcohol into vinegar.

1978 *Why does the housewife scald her preserved fruits to prevent their turning sour?*

Because fermenting substances and fermenting action are *destroyed* by a boiling temperature.

1979 *Why do we keep preserves, beer, cider, or other substances liable to turn sour, in a cool place?*

Because a depression of temperature *arrests fermen-*

tation, though it does not prevent its renewal when the temperature is increased.

1980 *What is ether?*

Ether is a product obtained by *distilling strong alcohol* and *sulphuric acid.* The product is called sulphuric ether, but it does not contain sulphuric acid, nor has it any sulphur in its composition.

1981 *What are the properties of ether?*

It is an *exceedingly volatile*, *inflammable* body, producing insensibility when inhaled, and readily dissolving all fatty and oily bodies.

1982 *Why will ether remove spots of oil, paint, or grease from garments?*

Because it is a *solvent* for all greasy, oily matters.

1983 *What are the best agents for depriving putrid and decaying animal and vegetable substances of their offensive odors?*

Chloride of lime is the most effectual agent; and *chloride of zinc* and *sulphate of iron* (green vitriol) are also exceedingly efficient. On a large scale, as in the sanatory cleansing of towns, pulverized charcoal, burnt clay, and quicklime, are to be recommended.

1984 *What effect does the use of perfumes or the burning of pastiles have upon offensive odors?*

They merely *disguise* the odor, but do *not remove or destroy it.*

1985 *By adopting what precautions may a person safely enter sick rooms, or visit, without risk, the most dangerous receptacles of filth?*

By moistening a linen cloth with vinegar, and sprinkling over it finely-powdered chloride of lime.

Air breathed through this, applied to the mouth and nostrils, will enter the lungs charged with a minute quantity of chlorine, which will effectually destroy any noxious vapors or miasms that escape from diseased bodies, or from decaying animal and vegetable substances.

1986 *What three conditions are requisite to produce putrefaction in animal and vegetable substances?*

It is necessary that they should be exposed to the combined influence of *air*, *heat*, and *moisture*.

1987 *Why is a substance preserved from decay by drying, or by the exclusion of air from it?*

Because by so doing we *remove* the *moisture* and *air* essential to the process of decay.

1988 *Why does the smoking of fish or flesh contribute to their preservation?*

Because the volatile matters of the smoke, such as creosote, pyroligneous acid, and the like, effect a species of *chemical combination* with the fibre of the meat, and with the substances contained in the natural juices of the flesh, which combinations are *less liable* to decay than the substances themselves.

1989 *What is albumen?*

Albumen is an *animal substance* as well as *vegetable.* It exists most abundantly, and in its purest natural state, in the *white of an egg*, from whence it derives its name (*album ovi*), which is the Latin for the white of an egg.

The serum or fluid portion of the blood (which, after exposure to the air, is separated from the more solid part) the vitreous and crystalline humors of the eye, the brain, the spinal marrow, and nerves, all contain albumen.

1990 *What is the yolk of an egg?*

This also consists of *albumen*, but contains in addition a *yellow oil*, which imparts to it its color.

1991 *Why is meat tough which has been boiled too long?*

Because the *albumen* becomes hard, like the white of a hard-boiled egg.

The best way of boiling meat to make it tender is this: Put your joint in very brisk boiling water; after a few minutes add a little cold water. The boiling water will *fix* the albumen, which will prevent the water from soaking into the meat, keep all its juices in, and prevent the muscular fibre from contracting. The addition of cold water will secure the cooking of the *inside* of the meat, as well as of the surface.

1992 *Why is meat always tough if it be put into the boiler before the water boils?*

Because the water is not hot enough to *coagulate* the albumen between the muscular fibres of the meat, which therefore runs into the water, and rises to the surface as scum.

1993 *Why is the flesh of old animals tough?*

Because it contains *very little* albumen, and much muscular fibre.

1994 *What is a poison?*

A poison is any agent capable of producing a dangerous effect upon anything endowed with life.

1995 *In cases of poisoning by substances taken into the stomach, what course should be pursued, in the absence of medical attendance?*

The first step is to evacuate the stomach by means of powerful emetics, and when vomiting has taken place, warm water and the white of eggs may almost always be given with advantage.

1996 *Can poisons administered for criminal purposes be almost certainly detected?*

They can; chemical science within the last few years has made such advances, that the most minute quantities of all the best known poisons can be detected with certainty long after death.

There is no poison *so liable* and *certain* to be found as *arsenic*, and in almost every case of poisoning with mineral poisons, science is enabled to detect the substance, even when life has been extinct for years, and the body nearly decomposed.

1997 *What is arsenic?*

Metallic arsenic is an *exceedingly brittle metal*, of a *steel-grey color.* It vaporizes, when heated, with a strong odor of garlic, a property not possessed by any other metal.

The substance used as poison, and sometimes known as ratsbane, is arsenious acid, a compound of arsenic and oxygen. Arsenious acid has the form and appearance of a fine white powder.

1998 *What is the best remedy in cases of poisoning with arsenic?*

The *hydrated peroxide of iron* (iron rust)* is considered the best remedy.

1999 *Is lead a poison?*

* The following is the best method for preparing this substance: Take common copperas (sulphate of iron) four ounces; dissolve in warm water in a glass, or porcelain dish, and add a small quantity of sulphuric acid, and afterwards ammonia solution, so long as a dense red precipitate is formed. This precipitate carefully strained off, and thoroughly washed in a filter with water, is hydrated peroxide of iron. So long as kept moist, it may be preserved for a great length of time.

Lead and nearly all its compounds are *dangerous* and *secret poisons;* when received into the system, it frequently remains dormant for years, and then suddenly manifests itself in various forms of disease.

2000 *What is the disease called "painters' colic?"*

A disease to which painters and others *working in lead are liable*, in consequence of receiving into their system, imperceptibly, portions of lead.

2001 *Is it dangerous to sleep in, or breathe the air of, a room newly painted with paints containing lead?*

It is *highly dangerous*, since the air is filled with a vapor of the lead compound used as paint.

2002 *Why are some waters, when conveyed through lead pipe, poisonous?*

Waters which are *very pure* and contain *much oxygen* dissolved in them; waters which contain *nitric acid* compounds, such as those flowing from the vicinity of barn-yards, manure heaps, and those which contain *common salt* or *organic matter*, as water flowing from swamps and fields; waters containing soluble *carbonates*—all dissolve lead from the pipes through which they may be made to pass Constant use of such waters, in the process of time, will introduce sufficient lead into the system to produce disease, which is often attributed to other causes.

2003 *What is verdigris?*

Verdigris is a compound of copper, oxygen, and acetic acid. This, and all the compounds of copper, are *very poisonous.* The most efficacious antidotes for poisoning with copper are, white of eggs and milk.

2004 *What is calomel?*

It is a compound of *two parts of mercury* united to one of *chlorine*, forming the sub-chloride of mercury. The preparation commonly known in medicine as "blue pill," is a preparation of mercury.

2005 *What is corrosive sublimate?*

A compound of *mercury and chlorine* united in equal proportions, forming the perchloride of mercury.

2006 *Are both these compounds, calomel and corrosive sublimate, poisons?*

They *are;* corrosive sublimate, especially, is a most *deadly poison.* In case of poisoning by it, the most effectual antidote is white of eggs.

2007 *What is the process of preserving wood from decay, commonly termed "kyanizing?"*

It consists in *saturating* the fibres of the wood with a *solution of corrosive sublimate.*

Poisonous substances, and corrosive sublimate especially, have the property of protecting animal and vegetable substances from decay. The skins of stuffed birds and animals, and the plants of a herbarium, may be protected from insects and decay, by washing them with a solution of corrosive sublimate. It should not, however, be forgotten, that these substances by such treatment become themselves poisonous.

2008 *What is contagion?*

We apply the term contagion to that *subtle matter* which proceeds from a *diseased person or body*, and which *communicates the disease* to another person or body.

Contagion differs from miasm in being the product of disease, and in reproducing itself.

2009 *What is miasm or miasmata?*

Miasm or miasmata is the *product of the decay or putrefaction of animal or vegetable substances*, and causes disease without being itself reproduced.

Contagion occasions disease in the same way that yeast excites fermentation. Miasm often acts, by its chemical properties merely, as a poison.

2010 *Why are contagious diseases sometimes communicated to individuals who merely approach the vicinity of diseased persons, but do not come in contact with or even see them?*

Because the *air* itself, which has been in contact with the diseased persons, *carries with it the seeds or germs of infection*, and thus communicates disease, sometimes at great distances.

2011 *Why are not all persons affected alike when exposed to similar contagious diseases?*

Contagious matter is not capable of producing disease, unless a *compound is present in the system capable of being decomposed by contact* with the exciting body.

2012 *What do we mean by susceptibility to contagion?*

We mean that the *blood* of a person *contains substances* by the decomposition of which the exciting body or contagion can be *reproduced.* If these substances are not present, and if the system be perfectly healthy, contagion will fail to produce disease.

2013 *What is the relative nutritive value of the different kinds of meat as food?*

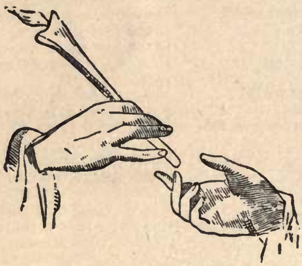
The relative nutritive value of the different meats for food is as follows: *beef* is the *most nutritious;* then *chicken*, *pork*, *mutton*, and *veal.*

2014 *What varieties of fish are the most nutritious?*

The *haddock*, the *herring*, the *salmon*, and the *eel*, in order.

2015 *What vegetable of ordinary consumption is the most nutritious?*

The *cabbage.*



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