



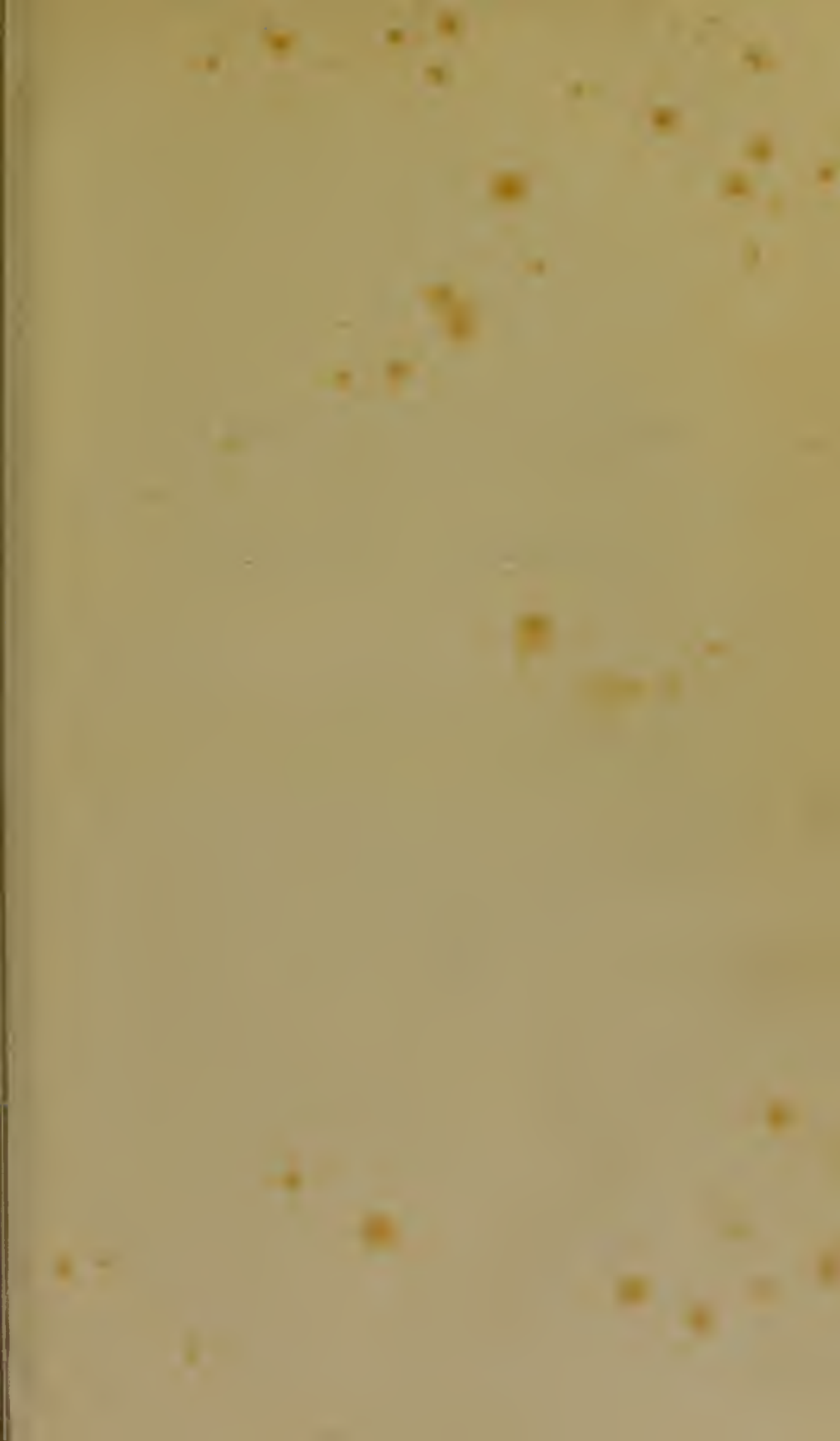
To
the
Honorable
Senate
of the
State of
California

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THE BRIDGEWATER TREATISES
ON THE POWER WISDOM AND GOODNESS OF GOD
AS MANIFESTED IN THE CREATION

TREATISE IV

THE HAND ITS MECHANISM AND VITAL ENDOWMENTS
AS EVINCING DESIGN

BY SIR CHARLES BELL K. G. H.

F. R. S. L. & E.

PROP. ROY. COLL. SURG. AND MEM. COUNCIL.

[THIRD EDITION]

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AS EVINCING DESIGN

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LONDON

WILLIAM PICKERING

1834

C. WHITTINGHAM, TOOKS COURT, CHANCERY LANE.

NOTICE.

THE series of Treatises, of which the present is one, is published under the following circumstances :

The RIGHT HONOURABLE and REVEREND FRANCIS HENRY, EARL OF BRIDGEWATER, died in the month of February, 1829 ; and by his last Will and Testament, bearing date the 25th of February, 1825, he directed certain Trustees therein named to invest in the public funds the sum of Eight thousand pounds sterling ; this sum, with the accruing dividends thereon, to be held at the disposal of the President, for the time being, of the Royal Society of London, to be paid to the person or persons nominated by him. The Testator further directed, that the person or persons selected by the said President should be appointed to write, print, and publish one thousand copies of a work *On the Power, Wisdom, and Goodness of God, as manifested in the Creation ; illustrating such work by all reasonable arguments, as for instance the variety and formation of God's creatures in the animal, vegetable, and mineral kingdoms ; the effect of digestion, and thereby of conversion ; the construction of the hand of man, and an infinite variety of other arguments ; as also by discoveries ancient and modern, in arts, sciences, and the whole extent of literature.* He desired, moreover, that the profits arising from the sale of the works so published should be paid to the authors of the works.

The late President of the Royal Society, Davies Gilbert, Esq. requested the assistance of his Grace the Archbishop of Canterbury and of the Bishop of London, in determining upon the best mode of carrying into effect the intentions of the Testator. Acting with their advice, and with the concurrence of a nobleman immediately connected with the deceased, Mr. Davies Gilbert appointed the following eight gentlemen to write separate Treatises on the different branches of the subject as here stated :

THE REV. THOMAS CHALMERS, D.D.

PROFESSOR OF DIVINITY IN THE UNIVERSITY OF EDINBURGH.

ON THE POWER, WISDOM, AND GOODNESS OF GOD
AS MANIFESTED IN THE ADAPTATION
OF EXTERNAL NATURE TO THE MORAL AND
INTELLECTUAL CONSTITUTION OF MAN.

JOHN KIDD, M.D. F.R.S.

REGIUS PROFESSOR OF MEDICINE IN THE UNIVERSITY OF OXFORD.

ON THE ADAPTATION OF EXTERNAL NATURE TO THE
PHYSICAL CONDITION OF MAN.

THE REV. WILLIAM WHEWELL, M.A. F.R.S.

FELLOW OF TRINITY COLLEGE, CAMBRIDGE.

ASTRONOMY AND GENERAL PHYSICS CONSIDERED WITH
REFERENCE TO NATURAL THEOLOGY.

SIR CHARLES BELL, K.G.H. F.R.S. L.&E.

THE HAND: ITS MECHANISM AND VITAL ENDOWMENTS
AS EVINCING DESIGN.

PETER MARK ROGET, M.D.

FELLOW OF AND SECRETARY TO THE ROYAL SOCIETY.

ON ANIMAL AND VEGETABLE PHYSIOLOGY.

THE REV. WILLIAM BUCKLAND, D. D. F. R. S.

CANON OF CHRIST CHURCH, AND PROFESSOR OF GEOLOGY IN THE
UNIVERSITY OF OXFORD.

ON GEOLOGY AND MINERALOGY.

THE REV. WILLIAM KIRBY, M. A. F. R. S.

ON THE HISTORY, HABITS, AND INSTINCTS OF ANIMALS.

WILLIAM PROUT, M. D. F. R. S.

CHEMISTRY, METEOROLOGY, AND THE FUNCTION OF
DIGESTION, CONSIDERED WITH REFERENCE
TO NATURAL THEOLOGY.

HIS ROYAL HIGHNESS THE DUKE OF SUSSEX, President of the Royal Society, having desired that no unnecessary delay should take place in the publication of the above mentioned treatises, they will appear at short intervals, as they are ready for publication.

PREFACE.

WHEN one has to maintain an argument, he will be listened to more willingly if he is known to be unbiassed, and to express his natural sentiments. The reflections contained in these pages have not been suggested by the occasion of the Bridgewater Treatises, but arose, long ago, in a course of study, directed to other objects. An anatomical teacher, who is himself aware of the higher bearings of his science, can hardly neglect the opportunity which the demonstrations before him afford, of making an impression upon the minds of those young men who, for the most part, receive the elements of their professional education from him; and he is naturally led to indulge in such trains of reflection as will be found in this essay.

So far back as the year 1813, the late excellent vicar of Kensington, Mr. Rennell, attended the author's lectures, and found him engaged in maintaining the principles of the English school of Physiology, and in exposing the futility of the opinions of those

French philosophers and physiologists, who represented life as the mere physical result of certain combinations and actions of parts, by them termed Organization.

That gentleman thought that the subject admitted of an argument which it became him to use, in his office of "Christian Advocate."* This will show the reader that the sentiments and the views, which a sense of duty to the young men about him induced the author to deliver, and which Mr. Rennell heard only by accident, arose naturally out of those studies.

It was at the desire of the Lord Chancellor that the author wrote the essay on "Animal Mechanics;" and it was probably from a belief that the author felt the importance of the subjects touched upon in that essay, that his lordship was led to do him the further honour of asking him to join with him in illustrating the "Natural Theology" of Dr. Paley.

That request was especially important, as showing that the conclusions to which the author had arrived, were not the peculiar or accidental suggestions of professional feeling, nor of solitary study, which is so apt to lead

* An office in the University of Cambridge.

to enthusiasm, but that the powerful and masculine mind of Lord Brougham was directed to the same object: that he, who in early life was distinguished for his successful prosecution of science, and who has never forgotten her interests amidst the most arduous and active duties of his high station, encouraged and partook of these sentiments.

Thus, from at first maintaining that design and benevolence were every where visible in the natural world, circumstances have gradually drawn the author to support these opinions more ostentatiously and elaborately than was his original wish.

The subject which he has to illustrate in this volume, belongs to no definite department; and is intermediate between those sciences which have been assigned to others. The conception which he has formed of its execution is, that setting out as from a single point, he should enlarge his survey and show the extent of the circle, and the variety of subjects which it bears upon; thence deducing the conclusion, that as there is a relation of one part to the whole, there must be a system, and universal design.

The author cannot conceal from himself the disadvantages to which he is exposed in

coming before the public, not only with a work, in some measure extra-professional, but with associates, distinguished by classical elegance of style, as well as by science. He must entreat the reader to remember that he was, early and long, devoted to the study of anatomy; and with a feeling (right or wrong) that it surpassed all other studies, in interest and usefulness. This made him negligent of those acquirements which would have better fitted him for the honourable association in which he has been placed: and no one can feel more deeply that the suggestions which occur in the intervals of an active professional life, must always be unfavorably contrasted with what comes of the learned leisure of a College.

The author has to acknowledge his obligations to His Grace the Archbishop of Canterbury, the Bishop of London, and the late President of the Royal Society, for having assigned to him a task of so much interest. When he undertook it, he thought only of the pleasure of pursuing these investigations, and perhaps too little of what the public were entitled to expect from an Essay composed in circumstances so peculiar, and forming a part in "this great argument."

CONTENTS.

	Page
CHAP. I. INTRODUCTORY—Object of the Volume	1
Consequence of viewing the Animal Body as a Machine	3
Relations of the Human Body to the surrounding Elements	5
Complexity of Structure consequent upon these relations	8
The Systematic Arrangement in an Animal Body implies a more universal design	9
Insensibility to the Provisions for Life and Security a species of ingratitude	13
 CHAP. II. DEFINITION OF THE HAND	 18
Its Mechanism	20
Conformity of the Skeleton to the Extremity	21
Bones of the Extremity not adapted to Man alone	22
Fossil Bones exhibit the Extent of the System	24
These studies not the ground of religious opinion, but conducive to a right condition of mind	27
Animals the most uncouth, in every Respect adapted to their Condition	27
Mistaken Compassion for Animals of peculiar Form	30
Animals suited to the progressive Changes of the Earth and Elements	35
Succession and Grouping of Animals	40
 CHAP. III. THE COMPARATIVE ANATOMY OF THE HAND	 45
Comparative View of the Anatomy of the <i>Shoulder</i>	49
The Arms wanting in a Boy	55
The Structure of the Horse's Shoulder	57
Of the Elephant and Camel	61

	Page
In the Batrachia	64
In the Chelonian Order	65
The <i>Humerus</i> . Spirit in which the Demonstration should be given	70
Peculiarities in the Mole	73
Bat	74
Ant-eater	76
Adaptation of the Anatomy in Birds	78
Of the Pterodaetyle	83
<i>The Anatomy of the Fore Arm</i>	84
Conclusions drawn from a Fragment of the Radius .	85
The Action of the Splint Bone in the Horse	93
Horse's Foot	94
Of Ruminants	96
Contrast in the Foot of the Elephant and the Camel	100
Megalonix	102
Mechanism of the Lion's Claw	103
Criticism by Cuvier	104
The Foot of the Quadrumana	106
Megatherium	108
Of Amphibia	109
Plesiosaurus and Ichthyosaurus	112
Peculiarities and Provisions of the Human Hand .	114
Relations of our subject with Geology—evinced in the successive revolutions of the earth's surface .	116
 CHAP. IV. OF THE MUSCLES OF THE ARM AND HAND	 124
Action of the Muscles of the Arm	125
Interchange of Velocity for Force, exemplified in the Muscles of the Arm	129
Illustrated by the Lever and Fly-Wheel	130
Muscles of the Lion's Extremity	136
Vital Property of the Muscles	137
Peculiarities in the Circulation of the Extremities as subservient to Muscular Action	138
Of the Right and Left Hands	140
 CHAP. V. THE SUBSTITUTION OF OTHER ORGANS FOR THE HAND	 143

CHAP. VI. THE ARGUMENT PURSUED FROM THE COM- PARATIVE ANATOMY	151
CHAP. VII. OF SENSIBILITY AND TOUCH	170
The Sensibility of the Surface compared with that of the deeper Parts	174
Pain the Safeguard of the Body	178
The protecting Sensibility of the Eye compared with the Sensibility of the Heart	182
Pleasurable Sensations could not have been the Mo- tives of Action	188
CHAP. VIII. OF THE SENSES GENERALLY INTRODUCTORY TO THE SENSE OF TOUCH	191
The Sense of Touch	198
Of the Cuticle	202
The Hoofs of Animals and their Sensibility	205
CHAP. IX. OF THE MUSCULAR SENSE	212
Of the Sensibility of the Infant to Impressions, and gradual Improvement of the Sense of Touch	212
Of the sense in Insects and Fishes	221
Loss of the Sense	225
Pleasures arising from the Muscular Sense	227
CHAP. X. THE HAND NOT THE SOURCE OF INGENUITY OR CONTRIVANCE, NOR CONSEQUENTLY OF MAN'S SUPERIORITY	230
The Capacities of the Mind correspond with the Instrument	232
Instincts. Young of the Alligator	234
Malignant Passions find their Instruments without Hands.—The Beggar of Moscow	235
The Subject illustrated by the Organs of Speech	236
Improved Ingenuity defeats the Ancient Arts of Design	239
Expression in the Hand. Quintilian	240
Changes in the Globe and successive Epochs	244
Concluding Remarks	250

ADDITIONAL ILLUSTRATIONS.

THE MECHANICAL PROPERTIES OF THE SOLID STRUCTURE OF THE ANIMAL BODY CONSIDERED . . .	261
Substitute for the Skeleton in the Lower Animals . . .	262
Mechanical Properties in Bone, or in the True Skeleton	267
Of the Muscular and Elastic Forces	278
<i>On the Position of the Head of Animals, and its Relation to the Spine: in illustration of the Statement made in the body of the Work, that ALL PARTS OF THE SKELETON CORRESPOND WITH EACH OTHER, AND THAT THE VARIATIONS IN THEIR FORM DEPEND SOLELY ON THE FUNCTIONS</i>	280
IMAGINARY ANIMALS	304
COMPARISON OF THE EYE WITH THE HAND	309
THE MOTION OF THE EYE CONSIDERED IN REGARD TO THE EFFECT OF SHADE AND COLOUR IN A PICTURE	330
EXPRESSION IN THE EYE	339

APPENDIX.

Explanation of Terms	343
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THE HAND,
ITS MECHANISM AND VITAL ENDOWMENTS,
AS EVINCING DESIGN.

CHAPTER I.

IF we select any object from the whole extent of animated nature, and contemplate it fully and in all its bearings, we shall certainly come to this conclusion : that there is design in the mechanical construction, benevolence in the endowments of the living properties, and that good on the whole is the result. We shall perceive that the sensibilities of the body have a relation to the qualities of things external, and that delicacy of texture is, therefore, a necessary part of its constitution. Wonderful, and exquisitely constructed, as the mechanical appliances are for the protection of this delicate structure, they are altogether insufficient ; and a protection of a very different kind, which shall animate the body to the utmost

exertion, is requisite for safety. Pain, whilst it is a necessary contrast to its opposite pleasure, is the great safeguard of the frame. Finally, as to man, we shall be led to infer that the pains and pleasures of mere bodily sense (with yet more benevolent intention) carry him onward, through the developement and improvement of the mind, to higher aspirations.

To comprehend the perfection of the structure even of any single organ of an animal body, we must take it comparatively, that we may see how the same system is adapted to an infinite variety of conditions. This carries us necessarily into a new science, no less than that which regards the changes in the Earth's surface; and although in this comparison we find that there have been stupendous revolutions indicative of power; it is in contemplating the new forms and adaptations of living and organized matter to these successive changes in the surface of the earth, that we have the best proofs of the continuance of that Power which first created.

Such is the course of reasoning which I propose to follow in giving an account of the hand and arm, contrasting them, in the first place, with the corresponding parts of living creatures, through all the divisions of the chain of vertebrated animals; and then taking the hand, not merely as combining the perfections of me-

chanical structure, but as possessed of the property of touch, by which it ministers to and improves every other sense, and constitutes the organ in the body the most remarkable in correspondence with man's capacities.

Some may conceive that as I have for my title the Human Hand, and the relation of the solid structures of the animal frame, it will lead me to consider the body as a machine only. I neither see the necessity for this, nor do I acknowledge the danger of considering it in that light. I embark fearlessly in the investigation, convinced that, yielding to the current of thought, and giving the fullest scope to enquiry, there can be no hidden danger if the mind be free from vicious bias. I cannot see how scepticism should arise out of the contemplation of the structure and mechanism of the animal body.

Let us for a moment think what is the natural result of examining the human body as a piece of machinery, and let us see whether it makes the creation of man more or less important in his relation to the whole scheme of nature.

Suppose that there is placed before us a machine for raising great weights, be it the simplest of all, the wheel and axle. We are given to understand that this piece of mechanism has the property of multiplying the power of the hand. But a youth of subtile mind may say, I do not believe that it is possible so to multiply the

power of the hand ; and if the mechanician be a philosopher, he will rather applaud the spirit of doubt. If he condescend to explain, he will say, that the piles driven into the ground, or the screws which unite the machinery to the beams, are the fixed points which resist in the working of the machine ; that their resistance is a necessary condition, since it is thrown, together with the power of the hand, on the weight to be raised ; and he will add that the multiplication of wheels does not alter the principle of action, which every one may see in the simple lever, to result from the resistance of the fulcrum or point, on which it rests.

Now grant that man's body is a machine, where are the points of resistance ? are they not in the ground he stands upon ? This leads us to enquire by what property we stand. Is it by the weight of the body, or, in other words, is it by the attraction of the earth ? The terms attraction, or gravitation lead at once to the philosophy of the question. We stand because the body has weight, and a resistance, in proportion to the matter of the animal frame and the magnitude of the globe itself. We need not stop at present to observe the adjustment of the strength of the frame, the resistance of the bones, the elasticity of the joints, and the power of the muscles, to the weight of the whole. Our

attention is directed to the relations which the frame has to the earth we are placed upon.

Some philosophers, who have considered the matter curiously, have said, that if man were translated bodily to another planet, and were it smaller than the earth, he would be too light, and he would walk like one wading in deep water. If the planet were larger, the attraction of his body would make him feel as if his limbs were loaded with lead; nay, the attraction might be so great as to destroy the fabric of the body, crushing bones and all.*

However idle these fancies may be, there is no doubt that the animal frame is formed with a due relation to the earth we inhabit, and that the parts of the animal body, and we may say the strength of the materials, have as certainly a correspondence with the weight, as the wheels and levers of a machine, or the scaffolding which sustains them, have relation to the force and velocity of the machinery, or the load that they are employed to raise.

The mechanism and organization of animals have been often brought forward for a different purpose from that for which I use them. We find it said, that it is incomprehensible that an all

* The matter of Jupiter is as 330,600 to 1000 of our Earth. The diameter of Pallas is 80 miles; the Earth is 7,911 miles in diameter.

powerful Being should manifest his will in this manner; that mechanical contrivance implies difficulties overcome: and how strange it is, they add, that the perceptions of the mind, which might have been produced by some direct means, or have arisen spontaneously, are received through an instrument so fine and complex as the eye;— and which requires the creation of the element of light, to enter the organ and to cause vision.

For my own part, I think it most natural to contemplate the subject quite differently. We perhaps presume too much, when we say that light has been created for the purpose of vision. We are hardly entitled to pass over its properties as a chemical agent, its influence on the gases, and, in all probability, on the atmosphere, its importance to vegetation, to the formation of the aromatic and volatile principles, and to fructification, its influence on the animal surface by invigorating the circulation, and imparting health. In relation to our present subject, it seems more rational to consider light as second only to attraction, in respect to its importance in nature, and as a link connecting systems of infinite remoteness.

To have a conception of this we must tutor our minds, and acquire some measure of the velocity of light, and of the space which it fills. It is not sufficient to say that it moves 200,000 miles in a second; for we can comprehend no such degree of velocity. If we are

further informed that the earth is distant from the sun 95,000,000 of miles, and that light traverses the space in 8 minutes and 1-8th, it is but another way of affirming the inconceivable rapidity of its transmission. Astronomers, whose powers of mind afford us the very highest estimate of human faculties, whose accuracy of calculation is hourly visible to us, have affirmed that light emanates from celestial bodies at such vast distance, that thousands of years shall elapse during its progress to our earth: yet matter impelled by a force equal to its transmission through this space, enters the eye, and strikes upon the delicate nerve with no other effect than to produce vision.*

Instead of saying that light is created for the eye, and to give us the sense of vision, is it not more conformable to a just manner of considering these things that our wonder and our admiration should fix on the fact, that this small organ, the eye, is formed with relation to a creation of such vast extent and grandeur:—and more especially, that the ideas arising in the mind, through the influence of that matter and this organ, are constituted a part of this vast whole!

By such considerations we are led to contemplate the human body in its different relations. The magnitude of the earth determines the

* The argument is not weakened on assuming the hypothesis, that light results from the movement of an elastic ether.

strength of our bones, and the power of our muscles; so must the depth of the atmosphere determine the condition of our fluids, and the resistance of our blood vessels; the common act of breathing, the transpiration from the surfaces, must bear relation to the weight, moisture, and temperature of the medium which surrounds us. A moment's reflection on these facts proves to us that our body is formed with a just correspondence to all these external influences: and not the frame of the body only, but also the vital endowments and the properties of the organs of sense. It were a perverseness to say that the outward senses, the organization, and vital properties could arise from the influence of the surrounding elements, or out of matter spontaneously; they are created in accordance with the condition of the globe, and are systematic parts of a great whole.

These views lead us to another consideration, that the complexity of our structure belongs to external nature, and not of necessity to the mind. Whilst man is an agent in a material world, and sensible to the influence of things external, complexity of structure is a necessary part of his constitution. But we do not perceive a relation between this complexity and the mind. From aught that we learn by this mode of study, the mind may be as distinct from the bodily organs as are the exterior influences which give them exercise.

Something, then, we observe to be common to our planet and to others, to our system and to other systems; matter, attraction, light; which nearly implies that the mechanical and chemical laws must be the same throughout. It is perhaps too much to affirm, with an anonymous author that an inhabitant of our world would find himself at home in any other, that he would be like a traveller only, for a moment perplexed by diversity of climate and strangeness of manners, and confess, at last, that nature was every where and essentially the same. However this may be, all I contend for is, the necessity of certain relations being established between the planet and the frames of all which inhabit it; between the great mass and the physical properties of every part; that in the mechanical construction of animals, as in their endowments of life, they are created in relation to the whole, planned together and fashioned by one Mind.

A comparison made between the system of an animal body, and the condition of the earth's surface, is highly illustrative of design in both. In the animal, we see matter withdrawn from the influences which arrange things that are dead and inorganic; but this matter thus appropriated to the animal, and newly endowed through the influence of life, continues in the possession of such qualities of inanimate matter as are necessary to constitute the living being a part of the

system—an inhabitant of the earth. To what then, does this argument lead? Is it not, that as the beautiful structure of the animal, and the perfection in the arrangement of its parts demonstrate design—that design extends to the condition of the earth also, and that there is a ruling Intelligence over both?

The passiveness which is natural in infancy, and the want of reflection as to the sources of enjoyment which is excusable in youth, become insensibility and ingratitude in riper years. In the early stages of life, before our minds have the full power of comprehension, the objects around us serve but to excite and exercise the outward senses. But in the maturity of reason, philosophy should present these things to us anew, with this difference, that the mind may contemplate them: that mind which is now strengthened by experience to comprehend them, and to entertain a grateful sense of them.

It is this sense of gratitude which distinguishes man. In brutes, the attachment to offspring for a limited period is as strong as in him, but it ceases with the necessity for it. In man, on the contrary, the affections continue, become the sources of all the endearing relations of life, and the very bonds by which society is connected.

If the child, upon the parent's knee, is unconsciously incurring a debt, and strong affections grow up so naturally that nothing is more universally condemned than filial ingratitude, we have but to change the object of affection, to find the natural source of religion itself. We must show that the care of the most tender parent is in nothing to be compared with those provisions for our enjoyment and safety, which it is not only beyond the ingenuity of man to supply to himself, but which he can hardly comprehend, while he profits by them.

If man, of all living creatures, be alone capable of gratitude, and through this sense be capable also of religion, the transition is natural; since the gratitude due to parents is abundantly more owing to Him "who saw him in his blood, "and said, Live."

For the continuance of life, a thousand provisions are made. If the vital actions of a man's frame were directed by his will, they are necessarily so minute and complicated, that they would immediately fall into confusion. He cannot draw a breath, without the exercise of sensibilities as well ordered as those of the eye or ear. A tracery of nervous cords unites many organs in sympathy, of which if one filament were broken, pain and spasm, and suffocation would ensue. The action of his heart, and the circulation of his blood, and all the vital func-

tions are governed through means and by laws which are not dependant on his will, and to which the powers of his mind are altogether inadequate. For had they been under the influence of his will, a doubt, a moment's pause of irresolution, a forgetfulness of a single action at its appointed time, would have terminated his existence.

Now, when man sees that his vital operations could not be directed by reason—that they are constant, and far too important to be exposed to all the changes incident to his mind, and that they are given up to the direction of other sources of motion than the will, he acquires a full sense of his dependance. If man be fretful and wayward, and subject to inordinate passion, we perceive the benevolent design in withdrawing the vital motions from the influence of such capricious sources of action, so that they may neither be disturbed like his moral actions, nor lost in a moment of despair.

Ray, in speaking of the first drawing of breath, delivers himself very naturally: “ Here, “ methinks, appears a necessity of bringing in “ the agency of some superintendent intelligent “ being, for what else should put the diaphragm “ and the muscles serving respiration in motion “ all of a sudden so soon as ever the fœtus is “ brought forth? Why could they not have “ rested as well as they did in the womb? What

“ aileth them that they must needs bestir them-
 “ selves to get in air to maintain the creature’s
 “ life? Why could they not patiently suffer it
 “ to die? You will say the spirits do at this
 “ time flow to the organs of respiration, the
 “ diaphragm, and other muscles which concur to
 “ that action and move them. But what raises
 “ the spirits which were quiescent, &c., I am
 “ not subtile enough to discover.”

We cannot call this agency, a new intelligence different from the mind, because, independently of consciousness, we can hardly so define it. But there is bestowed a sensibility, which being roused (and it is excited by the state of the circulation,) governs these muscles of respiration, and ministers to life and safety, independently of the will.

When man thus perceives, that in respect to all these vital operations he is more helpless than the infant, and that his boasted reason can neither give them order nor protection, is not his insensibility to the Giver of these secret endowments worse than ingratitude? In a rational creature, ignorance of his condition becomes a species of ingratitude; it dulls his sense of benefits, and hardens him into a temper of mind with which it is impossible to reason, and from which no improvement can be expected.

Debased in some measure by a habit of inattention, and lost to all sense of the benevolence of

the Creator, he is roused to reflection only by overwhelming calamities, which appear to him magnified and disproportioned ; and hence arises a conception of the Author of his being more in terror than in love.

There is inconsistency and something of the child's propensities still in mankind. A piece of mechanism, as a watch, a barometer, or a dial, will fix attention—a man will make journeys to see an engine stamp a coin, or turn a block ; yet the organs through which he has a thousand sources of enjoyment, and which are in themselves more exquisite in design and more curious both in contrivance and in mechanism, do not enter his thoughts ; and if he admire a living action, that admiration will probably be more excited by what is uncommon and monstrous, than by what is natural and perfectly adjusted to its office—by the elephant's trunk, than by the human hand. This does not arise from an unwillingness to contemplate the superiority or dignity of our own nature, nor from an incapacity of admiring the adaptation of parts. It is the effect of habit. The human hand is so beautifully formed, it has so fine a sensibility, that sensibility governs its motions so correctly, every effort of the will is answered so instantly, as if the hand itself were the seat of that will ; its actions are so

powerful, so free, and yet so delicate, that it seems to possess a quality instinct in itself, and there is no thought of its complexity as an instrument, or of the relations which make it subservient to the mind; we use it as we draw our breath, unconsciously, and have lost all recollection of the feeble and ill-directed efforts of its first exercise, by which it has been perfected. Is it not the very perfection of the instrument which makes us insensible to its use? A vulgar admiration is excited by seeing the spider-monkey pick up a straw, or a piece of wood, with its tail; or the elephant searching the keeper's pocket with his trunk. Now, fully to examine the peculiarity of the elephant's structure, that is to say, from its huge mass to deduce the necessity for its form, and from the form the necessity for its trunk, would lead us through a train of very curious observations to a more correct notion of that appendage, and therefore to a truer admiration of it. But I take this part in contrast with the human hand, merely to show how insensible we are to the perfections of our own frame, and to the advantages attained through such a form. We use the limbs without being conscious, or, at least, without any conception of the thousand parts which must conform to a single act. To excite our attention, we must either see the actions of the human frame performed in some

mode, strange and unexpected, such as may raise the wonder of the ignorant and vulgar ; or by an effort of the cultivated mind, we must rouse ourselves to observe things and actions, of which, as we have said, the sense has been lost by long familiarity.

In the following pages, I shall treat the subject comparatively, and exhibit a view of the bones of the arm, descending from the human hand to the fin of the fish. I shall in the next place review the actions of the muscles of the arm and hand ; then proceeding to the vital properties, I shall advance to the subject of sensibility, leading to that of touch ; afterwards, I shall show the necessity of combining the muscular action with the exercise of the senses, and especially with that of touch, to constitute in the hand what has been called the geometrical sense. I shall describe the organ of touch, the cuticle and skin, and arrange the nerves of the hand according to their functions. I shall then enquire into the correspondence between the capacities and endowments of the mind, and the external organs, and more especially the properties of the hand ; and conclude by showing that animals have been created with a reference to the globe they inhabit ; that all their endowments and various organization bear a relation to their state of existence, and to the elements around them ; that there is a plan universal, extending through

all animated nature, and which has prevailed in the earliest condition of the world; and that, finally, in the most minute or most comprehensive study of those things we every where see prospective design.



B.

C.



CHAPTER II.

WE ought to define the hand as belonging exclusively to man—corresponding in sensibility and motion with that ingenuity which converts the being who is the weakest in natural defence, to the ruler over animate and inanimate nature.

If we describe the hand as that extremity which has the thumb and fingers opposed to each other, so as to form an instrument of prehension, we embrace in the definition the extremities of the quadrumana or monkeys. But the possession of four hands by animals of that class implies that we include the posterior as well as the anterior extremities. Now the anterior extremity of the monkey is as much a foot as the posterior extremity is a hand; both are calculated for their mode of progression, climbing, and leaping from the branches of trees, just

as the tail in some species is converted to the same purpose, and is as useful an instrument of suspension as any of the four extremities.*



The armed extremities of a variety of animals give them great advantages; but if man possessed any similar provisions, he would forfeit his sovereignty over all. As Galen, long since, observed, “did man possess the natural armour of

* This is a sketch of the Coaita, or Spider Monkey, so called from the extraordinary length of its extremities, and its motions. The tail answers all the purposes of a hand, and the animal throws itself about from branch to branch, sometimes swinging from the foot, sometimes by the fore extremity, but oftener and with a greater reach by the tail. The prehensile part of the tail is covered only with skin, forming an organ of touch, as discriminating as the proper extremities. The Caraya, or Black howling

the brutes, he would no longer work as an artificer, nor protect himself with a breast-plate, nor fashion a sword or spear, nor invent a bridle to mount the horse and hunt the lion. Neither could he follow the arts of peace, construct the pipe and lyre, erect houses, place altars, inscribe laws, and through letters and the ingenuity of the hand hold communion with the wisdom of antiquity, at one time to converse with Plato, at another with Aristotle, or Hippocrates."

But the hand is not a distinct instrument ; nor is it properly a superadded part. The whole frame must conform to the hand, and act with reference to it. Our purpose will not be answered by examining it alone ; we must extend our views to all those parts of the body which are in strict connexion with the hand: For example, the bones from the shoulder to the finger ends, have that relation which makes it essential to examine the whole extremity ; and in order fully to comprehend the fine arrangement of the parts necessary to the motions of the fingers, we must also compare the structure of the human body with that of other animals.

monkey of Cumana, when shot, is found suspended by its tail round a branch. Naturalists have been so struck with the property of the tail of the Ateles, as to compare it with the proboscis of the elephant ; they have assured us that they fish with it.

The most interesting use of the tail is seen in the Opossum. The young of that animal entwine their tails around their mother's tail and mount upon her back, where they sit secure, while she escapes from her enemies.

Were we to limit our enquiry to the bones of the arm and hand in man, no doubt we should soon discover their provisions for easy, varied, and powerful action ; and conclude that nothing could be more perfectly suited to their purposes. But we must extend our views to comprehend a great deal more,—a greater design.

By a skeleton, is understood the system of bones, which being internal, gives the characteristic form to the animal, and receives the action of the exterior muscles. This system belongs, however, only to one part of the animal kingdom, that higher division,—the animalia vertebrata,* which includes the whole chain of beings, from man to fishes.

The function the most essential to life is respiration ; and the mode in which this is performed, that is to say, the manner in which the decarbonization of the blood is effected through its exposure to the atmosphere, produces a remarkable change in the whole frame-work of the animal body. Man, the mammalia, birds, reptiles, and fishes have much of the mechanism of respiration in common ; and there is a resemblance through them all, in the texture of the bones, in the action of the muscles, and in the arrangement of the nerves. They all possess the vertebral column or spine ; and the

* See the Classification at the end of the volume,—also the first of the ADDITIONAL ILLUSTRATIONS.

existence of this column not only implies an internal skeleton, but that particular frame-work of ribs, which is suited to move in breathing. But the ribs do not move of themselves, they must have appropriate muscles. These muscles must have their appropriate nerves: and for supplying these nerves there must be a spinal marrow. The spinal canal is as necessary to the spinal marrow as the skull is to the brain. So that we come round to understand the necessity of a vertebra* to the formation of the spinal marrow; and the reader may comprehend how much enters into the conception of the anatomist or naturalist, when the term is used, a vertebrated animal, viz:—an internal skeleton, a particular arrangement of respiratory organs, and a conformity in the nervous system.

It is to this superior division that I shall limit myself, in making a review of the bones of the upper extremity.

Were I to indulge in the admiration naturally arising out of this subject, and point out the strength and the freedom of motion in the upper extremity at the ball and socket joint of the shoulder,—the firmness of the articulation of the elbow, and yet how admirably it is suited to the co-operation of the hands,—the fineness of the

* *Vertebra* is the name given to the individual bones of the spine, or back-bone. See the explanation, in the Classification at the end of the volume, of Vertebral Animals.

motion of the hand itself, divided among the joints of twenty-nine bones, it might be objected to with some show of reason, and it might be said,—The bones and the forms of the joints which you are admiring, are so far from being peculiarly suited to the hand of man, that they may be found in any other vertebrated animal. But this would not abate our admiration, it would only induce us to take a more comprehensive view of nature, and remind us that our error was in looking at a part only, instead of embracing the whole system; where by slight changes and gradations hardly perceptible, the same bones are adjusted to every condition of animal existence.

We recognise the bones which form the upper extremity of man, in the fin of the whale, in the paddle of the turtle, and in the wing of the bird. We see the same bones, perfectly suited to their purpose, in the paw of the lion or the bear, and equally fitted for motion in the hoof of the horse, or in the foot of the camel, or adjusted for climbing or digging in the long clawed feet of the sloth or bear.

It is obvious, then, that we should be occupied with too limited a view of our subject, were we to consider the human hand in any other light than as presenting the most perfect combination of parts: as exhibiting the bones and muscles which in different animals are suited to parti-

cular purposes, so combined in the hand, as to perform actions the most minute and complicated, consistently with powerful exertion.

The wonder still is, that whether we examine this system in man, or in any of the inferior species of animals, nothing can be more curiously adjusted or appropriated; and we should be inclined to say, whatever instance occupied our thoughts for the time, that to this particular object the system had been framed. The view which the subject opens to us, is unbounded. The curious synthesis by which we ascertain the nature, condition, and habits of an extinct animal, from the examination of its fossil remains, is grounded on a knowledge of the system of which we are speaking; and to make the proper use of this department we must understand what a fossil bone is.

A bone consists of many parts; but for our present purpose it is only necessary to observe that the hard substance, the phosphate of lime, which we familiarly recognise as bone, is every where penetrated by membranes and vessels as delicate as those which belong to any other part of the body. Fossil bones are those which are found imbedded in the earth, and may be in different conditions. They either retain their animal part, or may have become petrified; that is to say, the animal matter may have been decomposed and dissipated, with the phosphoric

acid of the phosphate of lime; and then, silicious earth, or lime in composition with iron, or iron pyrites, may by solution and infiltration fill the interstices of the original earthy matter of the bone; thus it is converted into stone, and is as permanent as the rock which contains it. It retains the form, though not the internal structure of bone; and that form, in consequence of the perfect system which we have hinted at, becomes a proof of revolutions the most extraordinary. The mind of the enquirer is carried back, not merely to the contemplation of animal structure, but by inference, from the system of animal organization to the structure of the globe itself.

The remains of marine animals are found in the highest mountains of the old and new world, and great bones are discovered on turning up the surface of our fields; and in the beds of rivers; and not in the loose soil only, but under the solid limestone rock. The bones thus exposed, become naturally a subject of intense interest, and are unexpectedly connected with the enquiry in which we are engaged. Among other important conclusions they lead to this—that there is not only a scheme or system of animal structure pervading all the classes of animals which inhabit the earth, but that the principle of this great plan of creation was in operation, and governed the formation of those

animals which existed previous to the revolutions that the earth itself has undergone: that the excellence of form now seen in the skeleton of man, was in the scheme of animal existence long previous to the formation of man, and before the surface of the earth was prepared for him or suited to his constitution, structure, or capacities.

A skeleton is dug up which has lain under many fathoms of rock, being the bones of an animal that lived antecedent to that formation of rock, and at a time when the earth's surface must have been in a condition very different from what it is now. These remains prove, that all animals have been formed of the same elements, and have had analogous organs—that they received new matter by digestion, and were nourished by means of a circulating fluid—that they possessed feeling through a nervous system, and were moved by the action of muscles—that their organs of digestion, circulation, and respiration were modified by circumstances, as in the animals now alive, and in accordance with their habits and modes of living. The changes in the organs are but variations in the great system by which new matter is assimilated to the animal body,—and however remarkable these may be, they always bear a certain relation to the original type as parts of the same great design. In examining these bones of the

ancient world, so regularly are they formed on the same principle which is evident in the animals now inhabiting the earth, that on observing their shape, and the processes* by which their muscles were attached, we can reduce the animals to which they belonged, to their orders, genera, and species, with as much precision as if the recent bodies had been submitted to the eye of the anatomist. Not only can we demonstrate that their feet were adapted to the solid ground, or to the oozy bed of rivers, —for speed, or for grasping and tearing; but judging by these indications of the habits of the animals, we acquire a knowledge of the condition of the earth during their period of existence: that it was suited at one time to the scaly tribe of the lacertæ, with languid motion; at another, to animals of higher organization, with more varied and lively habits; and finally we learn, that at any period previous to man's creation, the surface of the earth would have been unsuitable to him.

We ought not to touch on this subject without one observation more. When the peasant suspends his work on turning up the great bones of

* Processes are the projecting parts of bone by which the tendons of the muscles are attached. The processes, therefore, to the anatomist are indications of the conditions of the muscles.

some unknown animal, and thinks that he has discovered the limbs of a giant, he is more excusable than the learned and ingenious, who desire to illustrate the Scriptures by these natural appearances. True religion is adapted to the sound capacities of every man—to that condition of mind which the individual experience of the good and evil of the world, sooner or later, brings with it. It is suited to man in every stage of the progress of society—to his weakness and to his strength, and by which it is the real dispenser of equal rights. Our religion could not have been adapted to every man, had it been framed with a relation to science, and least of all to that branch of natural knowledge which is called geology—a science so obviously in its infancy, that but for the alliance with anatomy, it would continue to present a scene only of confusion for ignorant wonderment. It may then be asked why we cultivate those scientific views to which we apply the term natural religion? Because they agreeably enlarge our comprehension, and exalt the imagination, while they repress a too selfish enthusiasm. We all have proceeded a certain length in the examination of natural phenomena, and the convictions arising from the survey are wrought into the opinions of every one. We experience a fresh and cheerful influence when benevolent design is disclosed to us by new facts, or by things familiar presented in a

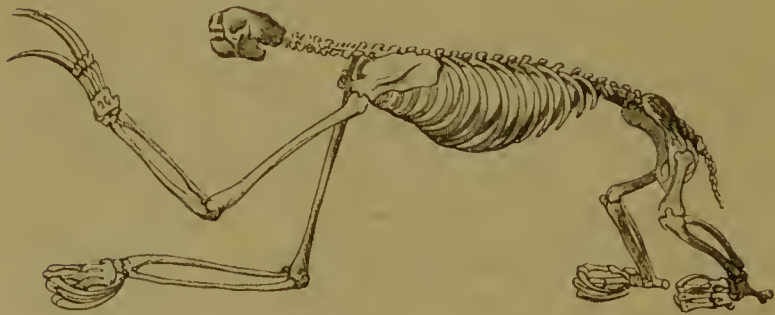
new light: we are sensible of a renewed impulse, a gratification which interferes with no duty.

We may take this opportunity to correct the notion which some have expressed, of imperfection in the structure of certain animals; an idea which has sprung from considering them in comparison with ourselves, our structure, and sensibilities, instead of looking on them with reference to their peculiar conditions.

On comparing some of the present races of animals with the fossil remains of individuals of the same family which are extinct, Buffon has expressed some singular opinions on their imperfections; and they have, with some reserve, been adopted even by Cuvier. The eloquent Buffon speaks confidently of the unsuitableness of the organs of animals, and the derangement of their instincts. He compares them with the state of human society, where individuals are subject to misery and want. He sympathizes too closely with the bird of prey when he characterises its watchfulness as a lively picture of wretchedness, anxiety, and indigence. If a bird refuses to be domesticated and crammed with meat, it is hardly fair in him to accuse it of gloom and apathy, when the simple fact is that he is treating it in a manner contrary to its natural habits and instincts. The animals I allude to, as more particularly connected with our subject, are of the tardigrade family; the

Ai,* in which, as these authorities believe, the defect of organization is the greatest; and the Unau,† which they consider only a little less miserably provided for existence.

Modern travellers, in the same manner, express their pity for these animals. Whilst other



quadrupeds, they say, range in boundless wilds, the sloth hangs suspended by his strong arms,—a poor ill-formed creature, deficient as well as deformed, his hind legs too short, and his hair like withered grass; his looks, motions, and cries conspire to excite pity; and, as if this were not enough, they say that his moaning makes the tiger relent and turn away. This is not a true picture: the sloth cannot walk, like quadrupeds, but he stretches out his arms,—and if he can hook on his claws to the inequalities of the ground, he drags himself along. This is

* *Bradypus Tridactylus*:—*bradypus* (*slow footed*), *tridactylus* (*three toed*), of the order EDENTATA (*wanting incisor teeth*).

† *Bradypus didactylus*.

the condition which authorizes such an expression as "the bungled and faulty composition of the sloth." But when he reaches the branch or the rough bark of a tree, his progress is rapid; he climbs hand over head along the branches till they touch, and thus from bough to bough, and from tree to tree; he is most alive in the storm, and when the wind blows, and the trees stoop, and the branches wave and meet, he is then upon the march.

The compassion expressed by these philosophers for animals,* which they consider imperfectly organized, is uncalled for; as well might they pity the larva of the summer fly, which creeps in the bottom of a pool, because it cannot yet rise upon the wing. As the insect has no impulse to fly until the metamorphosis is perfect, and the wings developed, so we have no reason to suppose that a disposition or instinct is given to animals without a corresponding provision for motion. The sloth may move tardily on the ground, his long arms and his preposterous claws may be an incumbrance, but they are of advantage in his natural place, among the branches of trees, in obtaining his food, and in giving him shelter and safety from his enemies.

We must not estimate the slow motions of animals by our own sensations. The motion of the bill of the swallow, or the fly-catcher, in

* The subject is pursued at the end of the following chapter.

catching a fly, is so rapid that we do not see it, but only hear the snap. On the contrary, how very different are the means given to the chameleon for obtaining his food; he lies more still than the dead leaf, his skin is like the bark of the tree, and takes the hue of surrounding objects. Whilst other animals have excitement conforming to their rapid motions, the shrivelled face of the chameleon hardly indicates life; the eyelids are scarcely parted; he protrudes his tongue with a motion so imperceptible towards the insect, that it is touched and caught more certainly than by the most lively action. Thus, various creatures living upon insects reach their prey by different means and instincts; rapidity of motion, which gives no time for escape, is bestowed on some, while others have a languid and slow movement that excites no alarm.



The loris, a tardigrade animal, might be pitied too for the slowness of its motions, if they

were not the very means bestowed upon it as necessary to its existence. It steals on its prey by night, and extends its arm to the bird on the branch, or the great moth, with a motion so imperceptibly slow, as to make sure of its object.* Just so, the Indian perfectly naked, his hair cut short, and his skin oiled, creeps under the canvass of the tent, and moving like a ghost, stretches out his hand, with a motion so gentle as to displace nothing, and to disturb not even those who are awake and watching. Against such thieves, we are told, that it is hardly possible to guard; and thus, the necessities or vicious desires of man subjugate him, and make him acquire, by practice, the wiliness which is implanted as instinct in brutes; or we may say that in our reason we are brought to imitate the irrational creatures, and so to vindicate the necessity for their particular instincts,

* For our purpose, it may be well to notice other characters of this, and similar animals which prowl by night. They are inhabitants of the tropical regions. Now, the various creatures which enliven the woods in the day-time, in these warm climates, have fine skins, and smooth hair; but those that seek their prey at night have a thick coat like animals of the arctic regions. What is this but to be clothed as the sentinel is clothed whose watch is in the night? They have eyes too, which, from their peculiarity, are called nocturnal, being formed to admit a greater pencil of rays of light. For this purpose the globe is large and prominent, and the iris contractile, to open the pupil to the greatest extent. We have seen how all their motions and instincts correspond with their nocturnal habits.

of which every class affords examples. We have them in insects, as striking as in the loris, or the chameleon. Evelyn describes the actions of the spider (*aranea scenica*) as exhibiting remarkable cunning in catching a fly. “Did the fly, (he says,) happen not to be within a leap, the spider would move towards it, so softly, that its motion seemed not more perceptible than that of the shadow of the gnomon of a dial.”*

I would only remark further on these motions of the muscles of animals, that we are not to account this slowness a defect, but rather an appropriation of muscular power: since in some animals the same muscles which move their members so as to be hardly perceptible, can at another time act with the velocity of a spring.

Now Buffon, speaking of the extinct species of the tardigrade family, considers them as monsters by defect of organization: as attempts of nature in which she has failed to perfect her plan: inferring that she has produced animals

* The passage continues—“if the intended prey moved, the spider would keep pace with it exactly as if they were actuated by one spirit, moving backwards, forwards, or on each side without turning. When the fly took wing, and pitched itself behind the huntress, she turned round with the swiftness of thought, and always kept her head towards it, though to all appearance as immoveable as one of the nails driven into the wood on which was her station; till at last, being arrived within due distance, swift as lightning she made the fatal leap, and secured her prey.”—Evelyn, as quoted by Kirby and Spence.

which must have lived miserably, and which are effaced as failures from the list of living beings. The Baron Cuvier does not express himself more favourably when he says of the existing species that they have so little resemblance to the organization of animals generally, and their structure is so much in contrast with that of other creatures, that he could believe them to be the remnants of an order unsuitable to the present system of nature; and if we are to look for their congeners, it must be in the interior of the earth, in the ruins of the ancient world.



The animals of the Antediluvian world were not monsters; there was no *lusus* or extravagance. Hideous as they appear to us, and like the phantoms of a dream, they were adapted to the condition of the earth when they existed. I could have wished that our naturalists had given the inhabitants of that early condition of the globe, names less scholastic. We have the plesiosaurus, and plesiosaurus dolichodeirus, we

have the ichthyosaurus, megalosaurus, and hylæosaurus, and iguanodon, pterodactyles, with long and short beaks, tortoises, and crocodiles; and these are found among reeds and grasses of gigantic proportions, algæ and fuci, and a great variety of mollusca of inordinate bulk compared with those of the present day, as ammonites and nautili. Every thing declares, that these animals inhabited shallow seas, and estuaries, or great inland lakes: that the surface of the earth did not rise up in peaks and mountains, or that perpendicular rocks bound in the seas; but that it was flat, slimy, and covered with a loaded and foggy atmosphere. Looking to the class of animals as we have enumerated them, there is a correspondence; they were scaly; they swam in water, or crept upon the margins; there were no animals possessed of rapidity of motion, and no birds of prey to stoop upon them; there was, in short, that balance of the power of destruction and of self-preservation which we see now to obtain in higher animals since created, with infinitely varied instincts and means for defence or attack. There is, indeed, every reason to believe that the classes mammalia and birds were not then created. If man had been placed in this condition of the earth, there must have been around him a state of things unsuited to his constitution, and not calculated to call forth his capacities.

It is hardly possible to watch the night and see the break of day in a fine country, without being sensible that our pleasantest perceptions refer to the scenery of nature, and that we have feelings in sympathy with every successive change, from the first streak of light until the whole landscape is displayed in valleys, woods, and sparkling waters; and the changes on the scene are not more rapid than the transitions of the feelings which accompany them. All these sources of enjoyment, the clear atmosphere and the refreshing breezes, are as certainly the result of the several changes which the earth's surface has undergone, as the displaced strata within its crust are demonstrative of these changes. We have every reason to conclude that these revolutions, whether they have been slowly accomplished and progressively, or by sudden, vast and successive convulsions, were necessary to prepare the earth for that condition which should correspond with the faculties to be given to man, and be suited to the full exercise of his reason, as well as to his enjoyment.

If a man contemplate the common objects around him—if he observe the connection between the qualities of things external and the exercise of his senses, between the senses so excited, and the condition of his mind, he will perceive that he is in the centre of a magnificent system, which has been prepared for his

reception by a succession of revolutions affecting the whole globe, and that the strictest relation is established between the intellectual capacities and the material world.

In the succeeding chapter we shall take a comparative view of the anatomy of the arm, and we shall be led to observe some very extraordinary changes in their forms, as we trace the same parts through different genera and species of animals. In doing this, we are naturally called upon to take notice of certain opinions which prevail on the subject.

We have already hinted, that geologists have discovered, that in the stratified rocks there is proof of a regular succession of formations in the crust of the earth, and that animals of very different structure have been imbedded, and are preserved in them. In the earlier formed strata animals are found which are low, as we choose to express it, in the chain of existence; in higher strata, oviparous animals of great bulk, and more complex structure, are discovered; above the strata containing these oviparous reptiles, there are found mammalia; and in the looser and more superficial stratum are the bones of the mastodon, megatherium, rhinoceros, and elephant, &c. We must add that geologists agree that man has been created last of all.

Upon these facts, a theory is raised, that

there has been a succession of animals gradually increasing in the perfection of their structure ; that the first impulse of nature was not sufficient to the production of the highest and most perfect, and that it was only in her mature efforts that mammalia were produced. We are led to this reflection : that the creation of a living animal, the bestowing of life on a corporeal frame, however simple the structure of that body, is of itself an act of creative power so inconceivably great, that we can have no title to presume that any change in the organization, such as the provision of bones and muscles, or the production of new organs of sense, is a higher effort of that power. We have a better guide in exploring the varieties of animated nature, when we acknowledge the manifest design with which all is accomplished ; the adaptation of the animals, their size, their economy, their organs, and instruments to their condition.

Whether we make the most superficial or most profound examination of animals in their natural state, we shall find that the varieties are so balanced as to ensure the existence of all. This, we think, goes far to explain, first, why the remains of certain animals are found in certain strata, which indicate a peculiar condition of the earth's surface ; and, secondly, why these animals are found grouped together. For, as we may express it, if there had been

an error in the grouping, there must have been a destruction of the whole ; the balance necessary to their existence having been destroyed. We know very well that so minute a thing as a fly will produce millions, which, if not checked, will ere long darken the air and render whole regions desolate : so that if the breeze does not carry them in due time into the desert or into the ocean, the destruction will be most fearful.

As in the present day every creature has its natural enemy ; or is checked in production, sometimes by a limited supply of food, sometimes by disease, or by the influence of seasons ; and as in the whole a balance is preserved, we may reasonably apply the same principle in explanation of the condition of things as they existed in the earlier stages of the world's progress ; certainly, this view is borne out, by what we have as yet discovered in the grouping of animals, in the different stratifications or deposits of the earth.

If the Naturalist or Geologist, exploring the rocks of secondary formation, should find animals of the class Mollusca inclosed within them, it agrees with his preconceived notions, that only animals of their simple structure were in existence at the time of the subsidence of that matter of which the rock consists. But if the spine of a fish, or a jawbone, or a tooth, be

discovered, he is much disturbed ; because, here is the indication of an animal having been at that time formed on a different type,—on that plan which belongs to animals of a superior class.—Whereas on the supposition that animals are created with that relation to circumstances which we have just alluded to, it would only imply that certain animals, which had hitherto increased undisturbed, had arrived at a period when their numbers were to be limited ; or that the condition of the elements, and the abundance of food were now suited to the existence of a species of the vertebrata.

The principle then, in the application of which we shall be borne out, is, that there is an adaptation, an established and universal relation between the instincts, organization, and instruments of animals, on the one hand, and the element in which they are to live, the position which they are to hold, and their means of obtaining food, on the other ;—and this holds good with respect to the animals which have existed, as well as those which now exist.

In discussing the subject of the progressive improvement of organized beings, it is affirmed that the last created of all, man, is not superior in organization to the others, and that if deprived of intellectual power, he is inferior to the brutes. I am not arguing to support the theory of the gradual developement and improvement

of organization; but, however indifferent to the tendency of the argument, I must not admit the statement. Man is superior in organization to the brutes,—superior in strength—in that constitutional property which enables him to fulfil his destinies by extending his race in every climate, and living on every variety of nutriment. On the other hand, gather together the most powerful brutes, from the arctic circle or torrid zone, to some central point—so ill suited is their constitution to the change, that they will die; diseases will be generated, and will destroy them. With respect to the superiority of man being in his mind, and not merely in the provisions of his body, it is no doubt true;—but as we proceed, we shall find how the Hand supplies all instruments, and by its correspondence with the intellect gives him universal dominion. It presents the last and best proof of that principle of adaptation which evinces design in the creation.

Another notion which we meet with, is, that the variety of animals is not a proof of design, as showing a relation between the formation of their organs and the necessity for their exercise; but that the circumstances in which the animal have been placed are the cause of the variety. The influence of these circumstances, it is pretended, has in the long progress of time, produced a complication of structure out of an

animal which was at first simple. We shall reserve the discussion of this subject until we have the data before us; which, of themselves, and without much argument, will suffice to overthrow it.

I may notice here another idea of naturalists, who are pleased to reduce these differences in the structure of animals into general laws. They affirm that in the centre of the animal body there is no disposition to change, whilst in the extremities we see surprising variations of form. If this be a law, there is no more to be said about it, the enquiry is terminated. But I contend that the term is quite inapplicable, and worse than useless, as tending to check enquiry. What then is the meaning of this variation in the form of the extremities and the comparative permanence towards the centre of the skeleton? I conceive the rationale to be this, that the central parts, by which in fact they mean the skull, spine, and ribs, are permanent in their offices; whilst the extremities vary and are adapted to every exterior circumstance. The office of the back part of the skull is to protect the brain, that of the spine to contain the spinal marrow, and of the ribs to perform respiration. Why should we expect these parts to vary in shape while their office remains the same? But the shoulder must vary in form, as it does in motion. The shape of the bones and the joints of the

extremities must be adapted to their various actions, and the carpus, or the tarsus, and phalanges* must change, more than all the rest, to accommodate the extremity to its different offices. Is it not more pleasing to see the reason of this most surprising adjustment, than merely to say it is a law? †

There is yet another opinion, which will suggest itself by the perusal of the following chapter, to those who have read the more modern works on Natural History. It is supposed that the same elementary parts belong to all animals, and that the varieties of structure are attributable to the transposition of these elementary parts. I find it utterly impossible to follow up this system to the extent which its abettors would persuade us to be practicable. I object to it as a means of engaging us in very trifling pursuits—and of diverting the mind from the truth; from that conclusion, indeed, to which I may avow it to be my intention to carry the reader. But this discussion also must follow the examples, and we shall resume it in a latter part of the volume.

* Carpus, the wrist; tarsus, the ankle or instep; phalanges, the rows of bones forming the fingers or toes.

† See the Additional Illustrations.



CHAPTER III.

The Comparative Anatomy of the Hand.

IN this enquiry, we have before us what in the strictest sense of the word is a system. All the individuals of the extensive division of the animal kingdom which we have to review, possess a cranium for the protection of the brain,—a heart, implying a peculiar circulation,—five distinguishable organs of sense; but the grand peculiarity, whence the term vertebrata is derived, is to be found in the spine; that chain of bones which connects the head and body, and, like a keel, serves as a foundation for the ribs, or as the basis of that fabric which is for respiration.

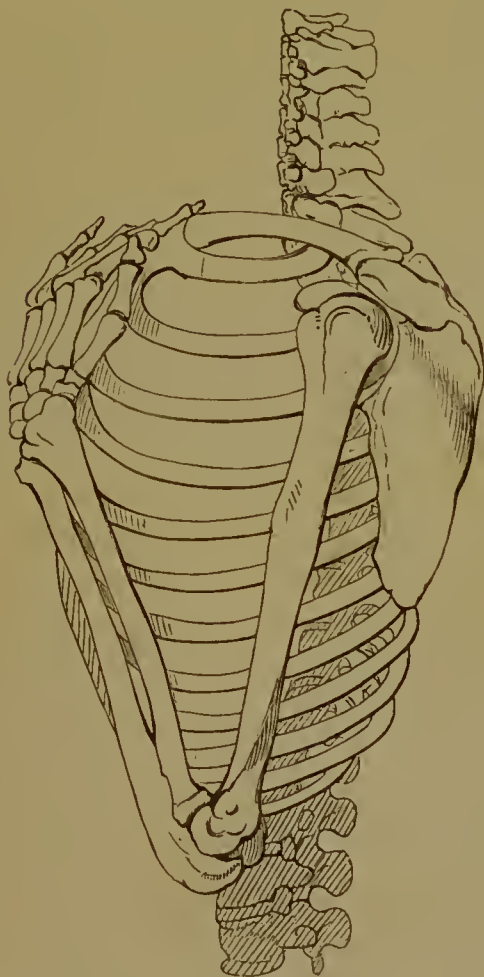
I have said, that we are to confine ourselves to a portion only of this combined structure; to separate and examine the anterior extremity, and to observe the adaptation of its parts, through the whole range of these animals. We

shall view it as it exists in man, and in the higher division of animals which give suck, the mammalia—in those which propagate by eggs, the oviparous animals,—birds, reptiles, amphibia, and fishes; and we shall find the bones which are identified by certain common features, adjusted to various purposes, in all the series from the arm to the fin. We shall recognise them in the mole, formed into a powerful apparatus for digging, by which the animal soon covers itself, and burrows its way under ground. In the wing of the eagle we shall count every bone, and find that they are adapted to a new element, as powerful to rise in the air, as the fin of the salmon is to strike through the water. The solid hoof of the horse, the cleft foot of the ruminant, the paw with retractile claws of the feline tribe, the long folding nails of the sloth, are among the many changes that are found in the adjustment of the chain of bones, which in man, ministers to the compound motions of the hand.

Were it my purpose to teach the elements of this subject, I should commence by examining the lowest animals, and trace the bones of the anterior extremity as they come to resemble the human arm, and to be employed for a greater variety of uses in the higher animals; but as my present object is illustration only, I shall begin with the human hand, and compare its parts.

With this view, I shall divide the extremity into the shoulder, arm, and hand, and treat each subdivision with a reference to its structure in animals.

OF THE SHOULDER.



In viewing the human figure, or human skeleton, in connexion with our present subject, we

remark the strength and solidity of the lower extremities, in contrast with the superior. Not only are the lower limbs longer and larger than those of any other animal, but the pelvis is wider, and the obliquity of the neck of the thigh bone greater. The distances of the large processes on the upper ends of the thigh bones (the trochanters,) from the sockets, are also greater than in any of the vertebrata. Altogether the strength of these bones, the size and prominence of their processes, the great mass of the muscles of the loins and hips, distinguish man from every other animal; they secure to him the upright posture, and give him the perfect freedom of the arms, for purposes of ingenuity and art.

At the head of this chapter is a sketch of the Chimpanzee,* an ape which stands high in the order of quadrumana; yet we cannot mistake

* *Simia troglodytes*, from the coast of Guinea, more human in its form, and more easily domesticated than the ourang-outang. We would do well to consider the abode of these creatures in a state of nature—vast forests, extending in impenetrable shade below, whilst above, and exposed to the light, there is a scene of verdure and beauty; this is the home of those monkeys and lemurs which have extremities like hands. In many of them the hinder extremity has the more perfect resemblance to a hand; and in the Coaita (p. 19) we see the great toe assuming the characters of a thumb, whilst in the fore paw the thumb is not distinguishable, being hid in the skin. In short, these paws are not approximations to the hand, corresponding with a higher ingenuity, but are adaptations of the feet to the branches on which the animals climb and walk.

his capacities: that the lower extremities and pelvis, or hips, were never intended to give him the erect posture, or only for a moment; but for swinging, or for a vigorous pull, who can deny him power in those long and sinewy arms.

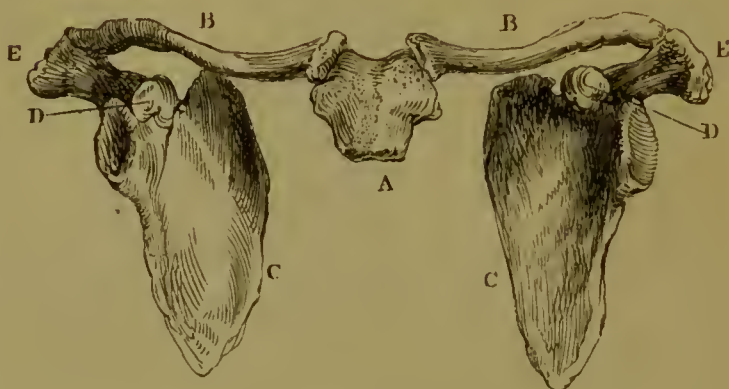
The full prominent shoulders, and the consequent squareness of the trunk, are equally distinctive of man with the strength of his loins; they indicate a free motion of the hand.

OF THE BONES OF THE SHOULDER.

The bones of the shoulder, being those which give firm attachment to the upper extremity, and which afford origins to the muscles of the arm and fore arm, are simple, if studied in man, or, indeed, in any one genus of animals; but considered in reference to the whole of the vertebral animals, they assume a very extraordinary degree of intricacy. We shall, however, find that they retain their proper office, notwithstanding the strange variations in the form of the neighbouring parts. In man they are directly connected with the great apparatus of respiration; but in other animals we shall see the ribs, as it were, withdrawn, and the bones of the shoulder, or fundamental bones of the extremity, curiously and mechanically adapted to perform their office without the support of the thorax. We shall not, however, anticipate the difficulties of this subject, but look first upon

that which is most familiar and easy, the shoulder of man in comparison with the varieties in the mammalia.

OF THE CLAVICLE.



The *clavicle*, or collar bone, is that which runs across from the breast bone to the top of the shoulder. The square form of the chest, and the free exercise of the hand, are very much owing to this bone. It keeps the shoulders apart from the chest, and throws the action of the muscles proceeding from the ribs upon the arm bone, which, but for it, would be drawn inwards, and contract the upper part of the trunk.

If we take the motions of the anterior extremity in different animals as our guide, we shall see why this bone is perfect in some, and entirely wanting in others. Animals which fly,

A. Triangular portion of the Sternum, or breastbone. B. B. Clavicles, or collar bones. c. c. Scapulæ, or shoulder blades. D. Coracoid process of the Scapulæ. E. Acromion process of the Scapulæ, forming the tip of the shoulder.

or dig, or climb, as bats, moles, porcupines, squirrels, ant-eaters, armadilloes, and sloths, have this bone, for in them, a lateral or outward motion is required. There is also a certain degree of freedom in the anterior extremity of the cat, dog, martin, and bear; they strike with the paw, and rotate the wrist more or less extensively, and they have therefore a clavicle, though an imperfect one. In some of these, even in the lion, the bone which has the place of the clavicle is very imperfect indeed; and if attached to the shoulder, it does not extend to the sternum: it is concealed in the flesh, and is like the mere rudiments of the bone. But, however imperfect, it marks a correspondence in the bones of the shoulder to those of the arm and paw, and the extent of motion enjoyed.



When the bear stands up, we perceive, by his ungainly attitude and the motion of his paws,

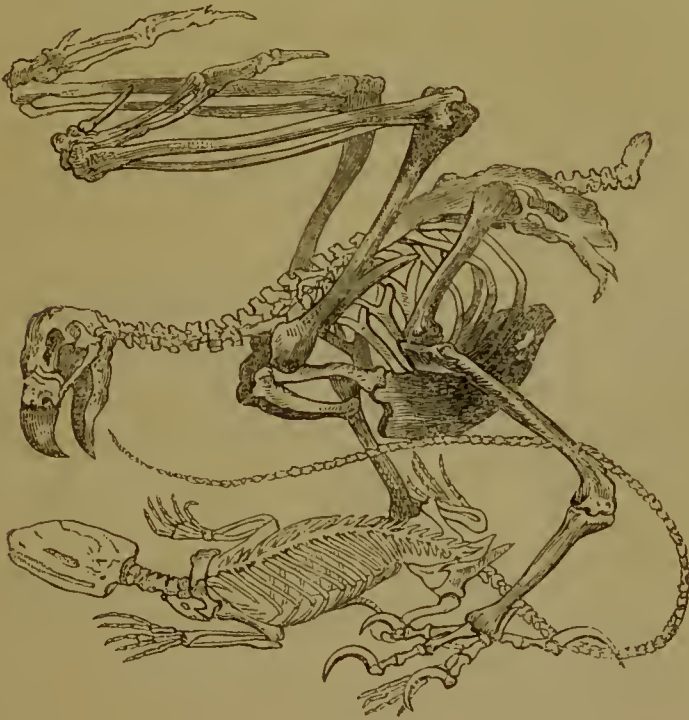
that there must be a wide difference in the bones of his upper extremity, from those of the ruminant or solipede. He can take the keeper's hat from his head, and hold it; he can hug an animal to death. The ant-bear especially, as he is deficient in teeth, possesses extraordinary powers of hugging with his great paws; and, although harmless in disposition, he can squeeze his enemy, the jaguar, to death. These actions, and the power of climbing, result from the structure of the shoulder, or from possessing a collar bone, however imperfect.

Although the clavicle is perfect in man, thereby corresponding with the extent and freedom of the motion of his hand, it is strongest and longest, comparatively, in the animals which dig or fly, as in the mole and the bat.

Preposterous as the forms of the kangaroo appear to us, yet even in this animal we see a relation preserved between the extremities. He sits upon his strong hind legs and tail, tripod like, with perfect security, and his fore paws are free. He has a clavicle, and possessing that bone and the corresponding motions, is not without means of defence; for with the anterior extremities he seizes the most powerful dog, and then, drawing up his hinder feet, he digs his sharp pointed hoofs into his enemy, and striking out, tears him to pieces. Though possessed of no great speed, and without horns, teeth, or claws,

and, as we should suppose, totally defenceless, nature has not been negligent of his protection.*

It cannot be better shown, that the function or use of a part, determines its form, than by looking to the clavicle and scapula of the bird.



Three bones converge here to the shoulder joint, the furculum, clavicle, and scapula; but

* There is in the form of the kangaroo, and especially in its skeleton, something incongruous, and in contrast with the usual shape of quadrupeds. The head, trunk, and fore paws, appear to be a portion of an animal unnaturally joined to another of greater dimensions and strength. It is not easy to say what are, or what were, the exterior relations corresponding with the very

none of these have the resemblance which their names would imply. The scapula is the long thin bone, like the blade of a knife; and the clavicle is that stronger portion of bone which is articulated with the breast bone; this leaves the furculum as a new part. Now I think that the furculum, or fork bone, which, in carving, we detach after removing the wings of a fowl, corresponds with the form and place of the clavicle; and if we so consider it, we may then take the strong bone commonly called the clavicle, as a process of the irregularly formed scapula. However this may be, what we have to admire in birds, is the mode in which the bones are fashioned to strengthen the articulation of the shoulder, and to give extent of surface for the attachment of the muscles which move the wings.

Another peculiarity in birds is, that there is not an alternate motion of the wings; their extremities, as we may continue to call them, move together in flying; and, therefore it is that the clavicles are joined to form the furculum.

peculiar form of this animal; but the interior anatomy is accommodated, in a most remarkable manner, to the enormous hinder extremities. The subject is taken up in the "Additional Illustrations" in the latter part of the volume, ON THE GENERAL FORM OF THE SKELETON.

OF THE SCAPULA.

IF we attend to the scapula, or shoulder-blade, we shall better understand the influence of the bones of the shoulder on the motions and speed of animals. The scapula is that flat triangular bone (see page 47), which lies on the ribs, and is cushioned with muscles. On its anterior angle there is a depressed surface, the glenoid cavity or socket for the arm bone. The scapula shifts and revolves with each movement of the arm. The muscles converge from all sides towards it, from the head, spine, ribs, and breast bone. These acting in succession, roll the scapula and toss the arm, in every direction. When the muscles combine in action, they fix the bone, and either raise the ribs in drawing breath, or give firmness to the whole frame of the trunk.

Before I remark further on the influence of the scapulæ on the motions of the arms, I shall give an instance in proof of a very important function which they perform. Hearing that there was a poor lad of fourteen years of age, born without arms, and whose unhappy condition had excited the benevolence of some ladies, I sent for him. I found that indeed he had no arms, but he had clavicles and scapulæ. When I made this boy draw his breath, the shoulders were raised, that is to say, the scapulæ were drawn up, were fixed, and became the points

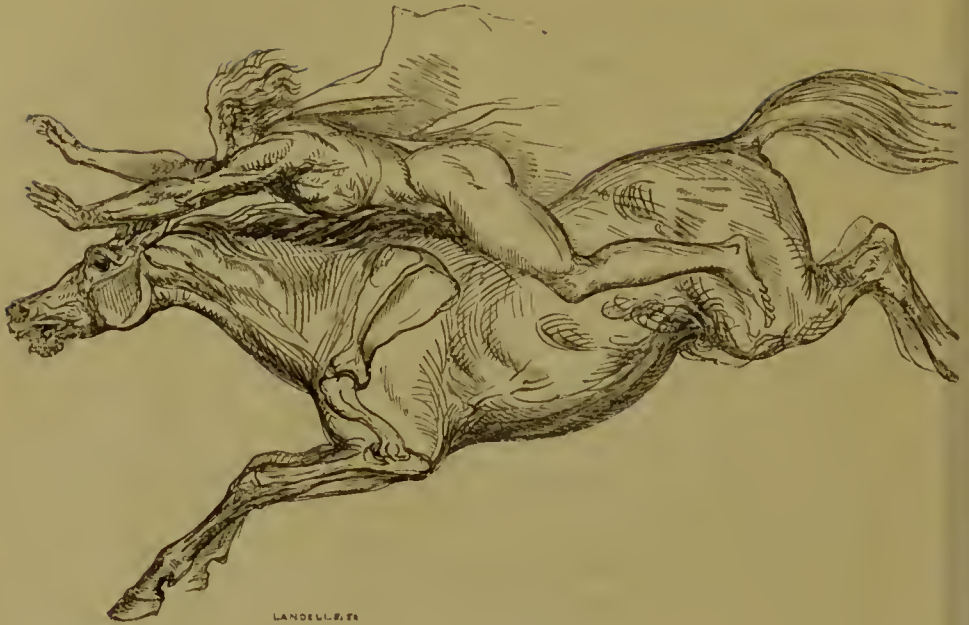
from which the broad muscles of the chest diverged towards the ribs, to draw and expand them in respiration. We would do well to remember this double office of the scapula and its muscles, that, whilst they are the very foundation of the bones of the upper extremity, and never wanting in any animal that has the most remote resemblance to an arm, it is the centre and point d'appui of the muscles of respiration, and acts, in that capacity, where there are no extremities at all!*

We perceive that it is only in certain classes of animals, that the scapula is joined to the trunk by bone, that is, through the medium of a clavicle; and a slight depression on a process of the scapula, when discovered in a fossil state, will therefore declare to the geologist the class to which the animal belonged. For example, there are brought over to this country the bones of the *Megatherium*, an animal which must have been larger than the elephant; of the anterior extremity there is only the scapula; and on the end of the process, called acromion, of that bone, there is a mark of the attachment of a clavicle. This points out the whole constitution of the extremity, and that it enjoyed perfect freedom of motion. Other circumstances will declare

* Some curious facts illustrative of this office of the muscles of the arm situated on the chest are stated in the author's paper on the *VOICE*, in the *Philosophical Transactions*. 1832.

whether that extensive motion was bestowed so that the animal might dig with its huge claws like some of the edentata, or strike like the feline tribe.

Some interest is attached to the position of the scapula, in the horse. In him, and in other quadrupeds, with the exceptions which I have made, there is no clavicle, and the connection between the extremity and the trunk is solely through muscles. That muscle called serratus magnus, which is a large one in man, is particularly powerful in the horse; for the weight of the trunk hangs upon this muscle. In the horse, as in most quadrupeds, the speed results from the strength of the loins and hinder extremities; for it is the muscles there which propel the animal. But were the anterior extremities joined to the trunk firmly, and by bone, they could not withstand the shock from the descent of the whole weight thrown forwards; even though they were as powerful as the posterior extremities, they would suffer fracture or dislocation. We cannot but admire, therefore, the provision in all quadrupeds whose speed is great, and whose spring is extensive, that, from the relative position of their bones, they have an elastic resistance, by which the shock of descending is diminished.



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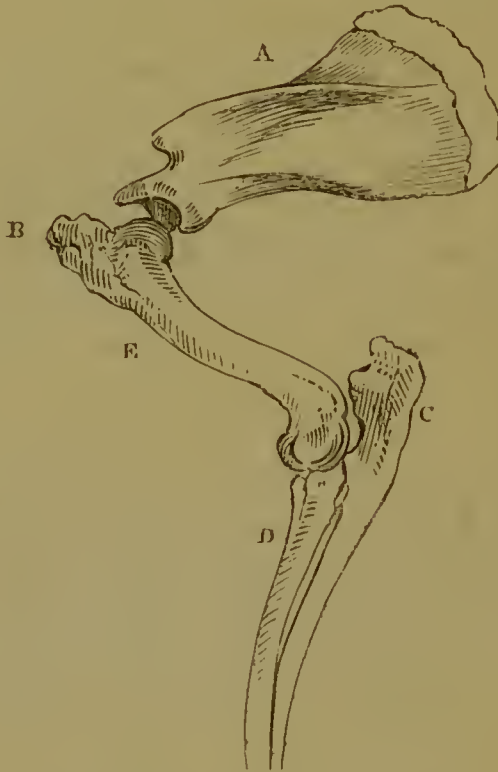
If we observe the bones of the anterior extremity of the horse, we shall see that the scapula is oblique to the chest; the humerus oblique to the scapula; and the bones of the fore arm at an angle with the humerus. Were these bones connected together in a straight line, end to end, the shock of alighting would be conveyed as through a solid column, and the bones of the foot, or the joints, would suffer from the concussion. When the rider is thrown forwards on his hands, and more certainly when he is pitched on his shoulder, the collar bone is broken, because in man, this bone forms a link of connection between the shoulder and the trunk, so

as to receive the whole shock; and the same would happen in the horse, the stag, and all quadrupeds of great strength and swiftness, were not the scapulæ sustained by muscles, and not by bone, and did not the bones recoil and fold up.

The horse-jockey runs his hand down the horse's neck, in a knowing way, and says, "this horse has got a heavy shoulder, he is a slow horse!" He is right, but he does not understand the matter; it is not possible that the shoulder can be too much loaded with muscle, for muscle is the source of motion, and bestows power. What the jockey feels, and forms his judgment on, is the abrupt transition from the neck to the shoulder, which, in a horse for the turf, ought to be a smooth undulating surface. This abruptness, or prominence of the shoulder, is a consequence of the upright position of the scapula; the sloping and light shoulder results from its obliquity. An upright shoulder is the mark of a stumbling horse: it does not revolve easily, to throw forward the foot.

Much of the strength, if not the freedom and rapidity of motion, of a limb, will depend on the angle at which the bones lie to each other; for, this mainly affects the insertion, and, consequently, the power of the muscles. We know, and may every moment feel, that when the arm is extended, we possess little power in bending it; but as we bend it the power is increased;

which is owing to the change in the direction of the force acting upon the bone; or, in other words, because the tendon becomes more perpendicular to the lever. A scapula which in-



clines obliquely backwards, increases the angle at which it lies with the humerus, or arm bone, and, consequently, improves the effect of those muscles which pass from it to that bone. We have only to turn to the skeleton of the elephant,

A. Scapula. E. Humerus, or arm-bone. B. Tuberosity of the Humerus. c. Olecranon, or projection of the Ulna. d. Radius.

the ox, the elk, or the stag, to see the confirmation of this principle. When the scapula is oblique, the serratus muscle, which passes from the ribs to its uppermost part, has more power in rolling it. When it lies at right angles with the humerus, the muscles which are attached to the latter, (at B.) act with more effect. And on the same principle, by the oblique position of the humerus, and, consequently, its obliquity in reference to the radius and ulna, the two bones of the fore-arm, the power of the muscle inserted (at C.) into the olecranon, is increased. On the whole, both power and elasticity are gained by this position of the superior bones of the fore-leg. It gives to the animal that springs, a larger stretch in throwing himself forwards, and security, in a soft descent of his weight. A man, standing upright, cannot leap or start off at once; he must first sink down, and bring the bones of his extremities to an angle. But the antelope, or other timid animals of the class, can leap at once, or start off in their course without preparation: another advantage of the oblique position of their bones when at rest.

These sketches with the pen are from the skeletons of the elephant and the camel. The leg of the former is obviously built for the purpose of sustaining the huge bulk of the animal, whilst in the camel we have a perfect contrast.



Were we to compare the bones of these larger animals with any form of architecture, it would be with the Egyptian, or rather they are like the Cyclopean walls of some ancient city ; they are huge and shapeless, and piled over each other, as if they were destined more to sustain weight, than to permit motion.

We further perceive, from the comparison of these sketches, that if the humerus be placed obliquely, it must necessarily be short, otherwise it would throw the leg too far back, and make the head and neck project. It is one of the "points" of a horse to have the humerus short. And not only have all animals of speed this character, but birds of long flight, as the swallow, have short humeri. This is owing, I think, to another circumstance, that in the wing, the short humerus causes a quicker extension ; for the further extremity of the bone moving in a lesser circle, makes the gyration be more rapid.

If we take the bones of the shoulder as a distinct subject, and trace them comparatively, we shall be led to notice some very curious modifications in them. We have already seen that there are two objects to be attained in the construction of these bones. In man, and mammalia, they constitute an important part of the organ of respiration ; and they conform to the structure of the thorax. But we shall find that

in some animals, this function is in a manner withdrawn from them; the scapulæ and the clavicles are left without the support of the ribs. These bones forming the shoulder, therefore, require additional carpentry; or they must be laid together on a new principle. In the batrachian order,* for example in the frog, the thorax, as constituted of ribs, has disappeared; the mechanism of respiration is altogether different from what it is in the mammalia. Accordingly, we find that the bones of the shoulder are on a new model; they form a broad and flat circle,†



sufficient to give secure attachment to the extremity, and affording a large space for the lodgement of the muscles which move the arm. Perhaps the best example of this structure is in the

* See the Appendix under the 3rd Class of Vertebrata, *Reptiles*.

† The Scapula, Clavicle, Sternum, and Coracoid bone may be recognised in this figure of the bones of a Frog.

siren and proteus; where the ribs are reduced to a very few imperfect processes, attached to the anterior dorsal vertebræ; and where the bones of the shoulder, being deprived of all support from the thorax, depend upon themselves for security. Here the bones corresponding to the sternum, clavicles, and scapulæ, are found cling-



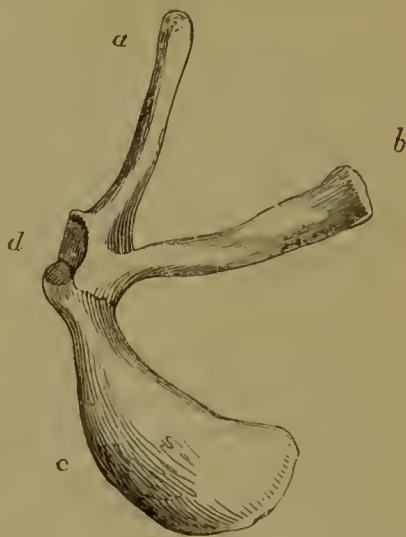
ing to the spine, and forming, like the pelvis,* a circle, to the lateral part of which the humerus or arm bone is articulated.

In the chelonian order,† the tortoises, we see another design accomplished, in the union of these bones; and the change is owing to a very curious circumstance. The spine and ribs of

* The pelvis is the circle of bones on which the spine or backbone rests, and in which are the sockets for the heads of the thigh bones.

† See again the Appendix, iii. Class of Vertebrata.

these animals are like rafters placed under the strong shell which covers them, and being united to the shell they are consequently external to the bones of the shoulder. The scapulæ and clavicles being thus within the thorax, and having nothing in their grasp, neither ribs nor spine, they must necessarily fall together, and form a circle, in order to afford fixed points to which the extremities may be attached. It would, indeed, be strange if now being joined for the purpose of giving attachment to the humerus, and in circumstances, as we may express it, so very new, they preserved any resemblance to the forms which we have been contemplating in the higher



animals. In this figure,* we have the bones of

* A. Scapula. B. Acromion process. c. Coracoid bone.
D. Glenoid cavity.

the shoulder of the turtle; and it is readily perceived how much they have changed both their shape and their offices. That part which is most like a scapula in shape, lies on the fore part instead of the back part; and the bones which hold the shoulders apart, abut upon the spine, instead of upon the sternum. Hence it appears idle to follow out these bones under the old denominations, or such as are applicable to their condition in the higher animals.

In fishes, where the apparatus of respiration has undergone another entire change, and where there are no proper ribs, the bones which give attachment to the pectoral fin, are still called the bones of the shoulder; and that which is named scapular appendage, is, in fact, attached to the bones of the head, instead of to the ribs or spine. So that the whole consists of a circle of bones, which, we may say, seek security of attachment by approaching the more solid part of the head, in defect of a firm foundation in the thorax.

Thus the bones which form the shoulder joint, and, in a manner, give a foundation to the anterior extremity, have been submitted to a new modelling in correspondence with every variety in the apparatus of respiration; and they have yet maintained their pristine office.

The naturalist will not be surprised on finding an extraordinary intricacy in the shoulder ap-

paratus of the *ornithorynchus paradoxus*, since the whole frame and organs of this animal imply that it is intermediate between mammalia and birds; it is placed in the list of edentata. It affords us another instance of the changes which the bones of the shoulder undergo with every new office, and in correspondence with the motions of the extremity; whether it be to support the weight in running, or to give freedom to the arm, or to provide for flying, or for performing equally the acts of creeping and of swimming.

Unprofitable as the enquiry may seem, there is no other way by which the geologist can distinguish the genera of those extinct and strangely formed oviparous reptiles which he finds imbedded in the secondary strata, than by studying the minute processes and varying characters of these bones, in the recent species. In the *ichthyosaurus*, and *plesiosaurus*, the inhabitants of a former world, we perceive a considerable deviation from the perfection of the bones of the arm and hand, compared with the frog and tortoise. But if strength be the object, there is a greater degree of perfection in the bones of the shoulder, in these extinct reptiles. The explanation of this is, that the ribs and sterno-costal arches, constituting the thorax, are more perfect than in the chelonian and batrachian orders; and the bones of the shoulder

are therefore external, and resemble those of the crocodile; yet the ribs are so weak as to be incapable of sustaining the powerful action of the muscles of the anterior extremities, or paddles; accordingly, the bones, which by a kind of license we continue to call clavicle, omoplate or scapula, and coracoid, though strangely deviating from the original form and connections, constitute a texture of considerable strength, which perfects the anterior part of the trunk, and gives attachment and lodgement to the powerful muscles of the paddle.

But in giving their attention to this subject, it does not appear that naturalists have hit upon the right explanation of the peculiar structure, and curious varieties of these bones, in the class of reptiles. Why is the apparatus of respiration so totally changed in these animals? They are cold blooded animals; they require to respire less frequently than other creatures, and they remain long under the water. I conceive that the peculiarity in their mode of respiration corresponds with this property. Hence their vesicular lungs, their mode of swallowing the air, instead of inhaling it; and hence, especially, their power of compressing the body and expelling the air. It is this provision for emptying the lungs, I imagine, which enables them to go under the water and crawl upon the bottom; without it, that is to say, had they possessed the

lungs of warm blooded animals, which are compressible only in a slight degree, their capacity of remaining under water would have left them struggling against their buoyancy, like a man, or any of the mammalia, when diving. The girdle of bones of the shoulder is constituted with a certain regard to the peculiar action of respiration, and to the pliancy of the body, in order that the vesicular lungs may be compressed, and the specific weight diminished. The facility which the absence of ribs gives, in the batrachian order, for admitting the compression of the lungs extended through the abdomen, and the extreme weakness and pliancy of the bones in the saurians, must be, as I apprehend, peculiarities adapted to the same end.

OF THE HUMERUS, OR ARM BONE.

The demonstration of this bone need not be so dry a matter of detail as the anatomist makes it. We may see in its form that curious relation of parts which has been so successfully employed by Paley to prove design, and from which the genius of Baron Cuvier has brought out some of the finest examples of inductive reasoning.

In looking to the head of this bone in the human skeleton, (see the fig. page 47,) we observe the great hemispherical surface for articulation with the glenoid cavity or socket of the scapula, and we see that the two tubercles for

the insertion of the muscles, near the joint, are depressed, and do not interfere with the revolving of the humerus, by striking against the edges of the socket. Such appearances alone are sufficient to show that all the motions of the arm are free.



To give assurance of this, and to illustrate how the form of the shoulder points to the structure of the whole arm, suppose that the geologist has picked up this bone in interesting circumstances. To what animal does it belong? The circular form

of the articulating surface, and the very slight projection of the tubercles, evince a latitude and extent of motion. Now, freedom of motion in the shoulder implies freedom also in the extremity or paw, and rotation of the bones of the wrist. Accordingly, we direct the eye to that part of this humerus which gives origin to the muscles for turning the wrist, (the *Supinator muscles*); and in the prominence and length of the ridge or crest which is on the lower and outer side of the bone, we have proof of the strength of these muscles, and consequently of the free motion of the paw.

Therefore, on finding the humerus thus characterized, we conclude, that it belonged to an

animal with sharp moveable claws ; that, in all probability, it is the remains of a bear.

But, suppose that the bone found has a different character:—That the tubercles project, so as to limit the motion to one direction, and that the articulating surface is less regularly convex. On inspecting the lower extremity of



such a bone, we shall perceive provisions for a deeper and more secure hinge joint at the elbow ; and neither in the form of the articulating surface, (which is here called trochlea,) nor in the crest or spine on the outside, above noticed, will there be signs of the rotation of one bone of the fore-arm on the other. We have, therefore, got the bone of an herbivorous quadruped, either with a solid or with a cloven foot.

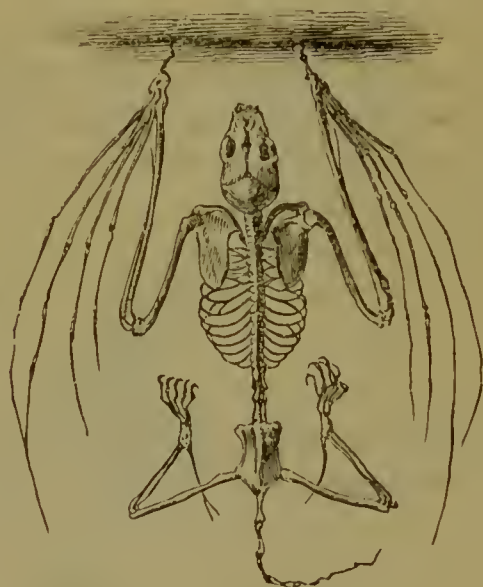
In the bat and mole we have, perhaps, the best examples of the moulding of the bones of

the extremity to correspond with the condition of the animal. The mole is an animal fitted to plough its way under ground. In the bat, the same system of bones is adapted to form a wing, to raise the animal in the atmosphere, with a provision for it to cling on the wall, not to bear upon. We recognise in both of these animals every bone of the upper extremity; but how very differently formed and joined! In the mole, the sternum or breast bone, and the clavicle are remarkably large: the scapula, or shoulder blade, assumes the form of a high lever: the humerus is thick and short, and has such prominent spines for the attachment of muscles, as to indicate great power. The spines which give origin to the muscles of rotation, project in an extraordinary manner; and the hand is large, flat, and so turned that it may shove the earth aside like a ploughshare.*



* The snout may vary in its internal structure with new offices. Naturalists say that there is a new "element" in the pig's nose. It has, in fact, two bones which admit of motion, whilst they give

There can be no greater contrast to these bones of the mole than is presented in the skeleton of the bat. In this animal the bones are light and delicate; and whilst they are all marvellously extended, the phalanges or the rows of bones of the fingers, are elongated so as hardly to be recognised, obviously for the pur-



more strength in digging the ground. Moles have those bones also, as they plough the earth with their snouts. We have noticed the manner in which they use their strong hands; we should add that their head is like a wedge, to which their hands are assisting in burrowing and throwing aside the earth. The conformation of the head, in shape and strength of bones, and the new adjustment of a muscle, which is cutaneous in other animals (the *Plutisma Myoides*) to assist in the motions of the head, are among the most curious changes of common parts to new offices. See again the "Additional Illustrations."

pose of sustaining a membraneous web, and to form a wing.

Contemplating this extraordinary application of the bones of the upper extremity, and comparing it with the wing of a bird, we might say, that in the bat, it is an awkward attempt—"a failure." But before giving expression to such an opinion, we must understand the objects required in this construction. It is not a wing intended merely for flight that the bat possesses, but one which, while it raises the animal, is capable of receiving a new sensation, or sensations in that exquisite degree so as almost to constitute a new sense. On the fine web of the bat's wing nerves are distributed, which enable it during the obscurity of night, when both eyes and ears fail, to avoid objects in its flight. Could the wing of a bird, covered with feathers, do this? Here then we have another example of the necessity of taking every circumstance into consideration before we presume to criticise the ways of nature. It is a lesson of humility.*

In the next page we have a sketch of the arm

* Besides the adaptation of the bat for flight, through a new adjustment of the bones of the arm, this animal has cells under its skin; but I know not how far I am authorized to say that they are analogous to the air-cells of birds, or that they are for the purpose of making the bat specifically lighter. They extend over the breast, and under the axillæ in some bats; and they are filled by an orifice which communicates with the pharynx.

bones of the Ant-eater,* to shew once more the correspondence that is maintained in the whole extremity. We observe these extraordinary spines of the humerus, indicating the power of



the muscles which are attached to it; for, as I have said before, whether we examine the human body, or the comparative forms of the bones, the distinctness with which the spines and processes are marked declares the strength of the muscles. It is particularly pleasing to notice here the correspondence between the humerus and the other bones,—the scapula large and with a double spine, and great processes: the ulna projecting at the olecranon or elbow, and the radius freely rotating: but above all, we see in the developement of one grand metacarpal bone and its

corresponding phalanges, to which a strong claw is attached, a very distinct provision for scratch-

* Tamandua, from South America.

ing and turning aside the ant-hill. The whole is an example of the relation of the particular parts of the skeleton to one another; for, were it our business, it would be easy to show that as there is a correspondence among the bones of the arm, so is there a more universal relation between those of the whole skeleton. As the structure of the bones declares the provision of the extremity for digging into the ant-hills, so we shall not be disappointed in our expectation of finding a projecting muzzle unarmed with teeth, and a long tongue provided with a glutinous secretion, to lick up the emmets which are disturbed by the animal's scratching.

In the skeleton of the cape-mole, we may see, from the projection of the acromion scapulæ, and a remarkable process in the middle of the humerus, that there is a provision for the rotation of the arm, which implies burrowing. But the apparatus is by no means so perfect as in the common mole, so that we may infer that the cape-mole digs in a softer soil; whilst the possession of gnawing teeth indicates that it lives on roots.

In BIRDS there is altogether a new condition of the osseous system, as there is a new element to contend with. The very peculiar form and structure of their skeleton may be thus accounted for. First, it is necessary that birds, as they are buoyed in the air, be specifically lighter.

Secondly, the circumference of their thorax must be extended, and the motions of their ribs limited, that the muscles of the wings may have sufficient space and firmness for their attachment. Both these objects are attained by a modification of the apparatus for breathing. The lungs are highly vascular and spongy, but they are not distended with air. The air is drawn through their substance, passing into the large cavity common to the chest and abdomen; and whilst the great office of decarbonization of the blood is securely performed, advantage is taken to let the air into all the cavities, even into those of the bones.

From what was said in the introductory chapter, of the weight of the body being a necessary concomitant of muscular strength, we see why birds, by reason of their lightness, as well as by the conformation of their skeleton, walk badly. And, on the other hand, in observing how this lightness is adapted for flight, it is remarkable how small an addition to their body will prevent them rising on the wing. If the griffon-vulture be frightened after his repast, he must disgorge, before he flies; and the condor, in the same circumstances, is taken by the Indians, like a quadruped, by throwing the lasso over it.*

As every one must have observed, the breast-

* The subject is continued in the "Additional Illustrations."

bone of birds extends the whole length of the body, so as to cover the great cavity common to the chest and abdomen, into which the air is admitted; and owing to this extension, a lesser degree of motion suffices to respiration. Thus a greater surface, necessary for the lodgement and attachment of the muscles of the wings, is obtained, whilst that surface is less disturbed by the action of breathing, and is more steady. Another peculiarity of the skeleton of the bird is the consolidation of the vertebræ of the back; a proof, if any were now necessary, that the whole system of bones conforms to that of the extremities, the firmer texture of the bones of the trunk being a part of the provision for the attachment of the muscles of the wings.*

The vertebræ of the back being fixed in birds, and the pelvis reaching high, there is no motion in the body; indeed, if there were, it would be interrupted by the sternum, or breast-bone. We cannot but admire, therefore, the structure of the neck and head, and how the length and pliability of the vertebræ of the neck, whilst they give to the bill the extent of motion and office of a hand, become a substitution for the loss of flexibility in the body, by enabling the bird to balance itself, as in standing, running, or flying. Is it not curious to

* The ostrich and cassowary, which are rather runners than fliers, have the spine loose.

observe how the whole skeleton is adapted to this one object, the power of the wings.



Whilst the ostrich has no keel in its breast-bone, birds of passage are recognisable, on dissection, by the depth of this ridge of the sternum. The reason is that the angle, formed by this process and the body of the bone, affords lodgement for the pectoral muscle, the powerful muscle of the wing. In this sketch of the dissection of the swallow, there is a curious resemblance to the human arm; and we cannot fail to observe that the pectoral muscle constitutes

the greater part of the bulk of the body.* And here we see the correspondence between the strength of this muscle and the rate of flying of the swallow, which is a mile in a minute, for ten hours every day, or six hundred miles a day.† If it be true that birds, when migrating, require a wind that blows against them,‡ it implies an extraordinary power, as well as continuance of muscular exertion.

We thus see how nature completes her work when the intention is that the animal shall rise buoyant and powerful in the air:—the whole texture of the frame is altered and made light, in a manner consistent with strength. We see also how the mechanism of the anterior extremity is changed, and the muscles of the trunk differently directed. But we are tempted to examine those means, which we would almost say are more awkwardly suited for their purpose, where the system of bones and muscles,

* Borelli makes the pectoral muscles of a bird exceed in weight all the other muscles taken together; whilst he calculates that the pectoral muscles of man are but a seventieth part of the whole mass of the muscles.

† Mr. White says truly, that the swift lives on the wing; it eats, drinks, and collects materials for its nest while flying, and never rests but during darkness.

‡ It is possible that the wind blowing near the ground in one direction may be attended with the motion of a higher stratum of the atmosphere in a contrary direction, and that, the idea of migrating birds flying against the wind may have arisen from this mistake.

peculiar to the quadruped, is preserved, while a power of launching into the air is also given. We have already taken notice of the structure of the bat as adapted to flight; but there are other animals which enjoy this function though in a lesser degree. For example, the flying squirrel (*Petromys Volucella*), being chased to the end of the bough, spreads out its mantle, which reaches along both its sides from the anterior to the posterior extremity, and drops in the air; and it is met during its descent with such a resistance from its extended skin and its bushy tail, that it can direct its flight obliquely downwards, and even turn in the air. But to this end, there is no necessity for any adaptation of the anterior extremity. Among reptiles, there is a provision of the same kind in the *Draco fimbriatus*; which is capable, after creeping to a height, of dropping safely to the ground, under the protection of a sort of parachute, formed by its extended skin. This is not an inapt illustration, for although the phalanges of the fingers are not here used to extend the web, the ribs, which are unnecessary for breathing, are prolonged in a remarkable manner, and upon them, like the whale-bone of an umbrella, the skin is expanded.

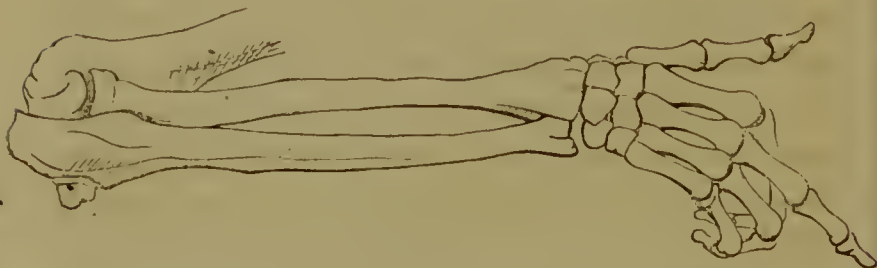
But this brings us to a very curious subject,—the condition of some of those Saurian reptiles, the remains of which are found only in a fossil

state, in what are termed the ancient strata of the Jura. The Pterodactyle of Cuvier is an animal which seems to confound all our notions of system. Its mouth was like the long bill of a bird, and its flexible neck corresponded; but it had teeth in its jaws like those of a crocodile. It had the bones of the anterior extremity prolonged, and fashioned somewhat like those in the wing of a bird; but it could not have had feathers, as it had not a proper bill. We see no creature having feathers without a bill to dress and prin them. Nor did this extremity resemble in its structure that of a bat: instead of the phalanges or rows of bones of all the fingers being equally prolonged, as in the bat, the second finger only was extended to an extraordinary length, whilst the third, fourth, and fifth had the length and articulation of those of a quadruped, and they were terminated with sharp nails, corresponding with the pointed teeth. The extended metacarpal bone and phalanges reached to double the whole length of the animal, and the conjecture is, that there was extended upon them a membrane resembling that of the *Draco fimbriatus*. In the imperfect specimens which we have to found our reasoning upon, we cannot discover either in the height of the pelvis, the strength of the vertebræ of the back, or the expansion of the sternum, a provision for the attachment of muscles commensurate with the extent of the supposed wing.

The humerus, and the bones which we presume to be the scapula and coracoid, bear some correspondence to the extent of the wing; but the extraordinary circumstance of all is the size and strength of the bones of the jaw and vertebræ of the neck, compared with the smallness of the body, and the extreme delicacy of the ribs; which make it, altogether, the thing the most incomprehensible in nature.

OF THE RADIUS AND ULNA.

The easy motion of the hand, we might imagine to result from the structure of the hand itself; but, on the contrary, the movements which appear to belong to it, are divided among all the bones of the extremity.*



The head of the humerus is rotatory on the scapula, as when making the guards in fencing; but the easier and finer rolling of the wrist is

* In this sketch, the upper bone of the fore-arm is the radius, and in revolving on the lower bone, the ulna, it carries the hand with it.

accomplished by the motion of the radius on the ulna.

The ulna has a hooked process, the olecranon, or projecting bone of the elbow, which catches round the lower end of the humerus or arm bone, (this articulating portion is called trochlea), and forms with it a hinge joint. The radius, again, at the elbow, has a small, neat, round head, which is bound to the ulna by ligaments, as a spindle is held in the bush; and it has a depression with a polished surface for revolving on the condyle of the humerus. This bone turns on its long axis, rolling upon the ulna both at the elbow and wrist-joint; and, as it turns, it carries the hand with it, because the hand is strictly attached to its lower head alone. This rolling, is what is termed pronation and supination.

Such a motion would be useless, and a source of weakness in an animal that had a solid hoof. Accordingly, in the horse, these bones are united together, and consolidated in the position of pronation.

But let us extend our views before we take the particular instance. There is indeed something so highly interesting in the conformation of the whole skeleton of an animal, and the adaptation of any one part to all the other parts, that we must not let our reader remain ignorant of the facts, or of the important conclusions

drawn from them. What we have to state has been the result of the studies of many naturalists; but although they have laboured, as it were, in their own department of comparative anatomy, they have failed to seize upon it with the privilege of genius, and to handle it in the masterly manner of Cuvier.

Suppose a man ignorant of anatomy to pick up a bone in an unexplored country, he learns nothing, except that some animal has lived and died there; but the anatomist can, by that single bone, estimate, not merely the size of the animal, as well as if he saw the print of its foot, but the form and joints of the skeleton, the structure of its jaws and teeth, the nature of its food, and its internal economy. This, to one ignorant of the subject, must appear wonderful, but it is after this manner that the anatomist proceeds. Let us suppose that he has taken up that portion of bone in the limb of the quadruped which corresponds to the human radius; and that he finds that the form of the bone does not admit of free motion in various directions, like the paw of the carnivorous creature. It is obvious, by the structure of the part, that the limb must have been merely for supporting the animal, and for progression, and not for seizing prey. This leads him to the fact that there were no bones resembling those of the hand and fingers, or those of the claws of

the tiger ; for the motions which that conformation of bones permits in the paw, would be useless, without the rotation of the wrist—he concludes that these bones were formed in one mass, like the cannon bone, pastern bones, and coffin bone of the horse's foot.*

The motion of the foot of a hoofed animal, limited to flexion and extension, implies the absence of a collar bone and a restrained motion in the shoulder joint ; and thus the naturalist, from the specimen in his hand, has got a perfect notion of all the bones of the anterior extremity ! The motions of the extremities imply a condition of the spine which unites them. Each bone of the spine will have that form which permits the bounding of the stag, or the galloping of the horse, but it will not have that manner of joining which admits of the turning or writhing of the spine, as in the leopard or the tiger.

And now he comes to the head :—the teeth of a carnivorous animal, he says, would be useless to rend prey, unless there were claws to hold it, and a mobility of the extremities like that of the hand, to grasp it. He considers, therefore, that the front teeth must have been for brousing, and the back teeth for grinding.

* For these are solid bones, where it is difficult to recognise any resemblance to the metacarpus and bones of the fingers ; and yet comparative anatomy proves that the latter bones are of the same class with those in the solidungula.

The socketing of the teeth in the jaws gives a peculiar form to these bones, and the muscles which move them are also peculiar; in short, he forms a conception of the shape of the skull. From this point he may set out anew, for by the form of the teeth, he ascertains the nature of the stomach, the length of the intestines, and all the peculiarities which mark a vegetable feeder.

Thus the whole parts of the animal system are so connected with one another, that from one single bone or fragment of bone, be it of the jaw, or of the spine, or of the extremity, a really accurate conception of the shape, motions, and habits of the animal, may be formed.

It will readily be understood that the same process of reasoning will ascertain, from a small portion of a skeleton, the existence of a carnivorous animal, or of a fowl, or of a bat, or of a lizard, or of a fish; and what a conviction is here brought home to us, of the extent of that plan which adapts the members of every creature to their proper office, and yet exhibits one system to pervade the whole range of animated beings whose motions are conducted by the operation of muscles and bones!

After all, this is but a part of the wonders disclosed through the knowledge of a thing so despised as a fragment of bone. It carries us into another science; since the knowledge of the skeleton not only teaches us the classification of

creatures now alive, but affords proofs of the former existence of animated beings which are not now to be found on the surface of the earth. We are thus led to an unexpected conclusion from such premises: not merely of the existence of an individual animal, or race of animals; but even the changes which the globe has undergone in times before all existing records, and before the creation of human beings to inhabit the earth, are opened to our contemplation.

To return to our particular subject, we readily comprehend how it happens that if the geologist should find the nearer head of the radius, resembling this sketch, and see in the extremity of it



a smooth depression (A), where it bears against the humerus, and the polished circle (B) that turns on the cavity of the ulna,—he would say,—this animal had a paw—it had a motion at the wrist, which implies claws. But claws may belong to two species of animals: the feline, which possesses sharp carnivorous teeth, or to

animals without either canine or cutting teeth, the Edentata. If he should find the lower extremity of this same bone, and observe on it spines and grooves for distinct tendons which disperse to the phalanges instead of running to be inserted into a single bone, he would conclude that there must have been moveable claws—that it belonged to a carnivorous animal; and he would seek for canine teeth of corresponding size.

THE LAST DIVISION OF THE BONES OF THE ARM.

In the human hand, the bones of the wrist (carpus) are eight in number; and they are so closely connected that they form a sort of ball, which moves on the end of the radius. Beyond these, and towards the fingers, forming the palm of the hand, are the metacarpal bones, which diverge at their further extremities, and give support to the bones of the fingers. The thumb has no metacarpal bone, and is directly articulated with the carpus or wrist. There are thus in the hand twenty-nine bones, from the mechanism of which result strength, mobility and elasticity.

Lovers of system (I do not use the term disparagingly) delight to trace the gradual sub-

traction of the bones of the hand. Thus, looking to the hand of man, they see the thumb fully formed. In the simiæ they find it exceedingly small; in one of them, the spider-monkey, it has disappeared, and the four fingers are sufficient, with hardly the rudiments of a thumb. In some of the tardigrade animals, as we have seen (in page 30) there are only three metacarpal bones with three fingers. In the horse, the cannon bone may be shewn to consist of two metacarpal bones. Indeed, we might go further and instance the wing of the bird. To me, this appears to be losing the sense in the love of system. There is no regular gradation, but, as I have often to repeat, a variety most curiously adapting the same system of parts to every necessary purpose.

In a comparative view of these bones, we are led more particularly to take notice of the foot of the horse. It is universally admitted to be of beautiful design, and calculated for strength and elasticity, and especially provided against concussion.

The bones of the fore-leg of the horse become firmer as we trace them downwards. The two bones corresponding with those of the fore-arm, are braced together and consolidated; and the motion at the elbow joint is limited to flexion and extension. The carpus, forming what by a sort of license is called the knee, is also newly

modelled; but the metacarpal bones and phalanges of the fingers are totally changed, and can hardly be recognised. When we look in front, instead of the four metacarpal bones we see one strong bone, the cannon bone; and posterior to this, we find two lesser bones, called splint bones. The heads of these lesser bones enter into the knee-joint; but at their lower ends they diminish gradually, and they are held by an elastic ligamentous attachment to the sides of the cannon bone.

I have some hesitation in admitting the correctness of the opinion of veterinary surgeons on this curious piece of mechanism. They imagine that these moveable splint bones, by playing up and down as the foot is alternately raised and pressed to the ground, bestow elasticity and prevent concussion. The fact certainly is that by over action this part becomes inflamed, and the extremities preternaturally joined by bone to the greater metacarpal or cannon bone; and that this, which is called a splint, is a cause of lameness.

I suspect, rather, that in the perfect state of the joint, these lesser metacarpal bones act as a spring to throw out the foot, when it is raised and the knee-joint bent. If we admit that it is the quickness in the extension of this joint on which the rate of motion must principally depend, it will not escape observation, that in the

bent position of the knee, the extensor tendons have very little power, from their running so near to the centre of motion in the joint; and that, in fact, they require some additional means to aid the extension of the leg.



Suppose that the head of the lesser metacarpal bone A enters into the composition of the joint, it does not appear that by its yielding when the foot is upon the ground, the bones of the carpus can descend, as long as they are sustained by the greater metacarpal or cannon bone. I do not, therefore, conceive that this bone can add to the

elasticity of the foot. But when we perceive that the head of the splint bone is behind the centre of motion in the joint, it is obvious that it must be more pressed upon in the bent condition of the joint, when the foot is elevated; and that then the bone must descend. If the splint bone be depressed when the limb is raised and bent, and have a power of recoiling (which it certainly has), it must aid in throwing out the leg into the straight position and assist the extensor muscles of the knee. Further, we can readily believe that when the elasticity of these splint bones is lost, by ossification uniting them firmly to the cannon bone, the want of such a piece of mechanism, essential to the quick extension of the foot, will make the horse apt to come down.

In looking to this sketch and comparing it with that of the hand on page 84, we see that in the horse's leg the five bones of the first digital phalanx are consolidated into the large pastern bone; those of the second phalanx into the lesser pastern or coronet; and those of the last phalanx into the coffin bone.

OF THE HORSE'S FOOT.—Nothing is better suited to illustrate our subject than the horse's foot. It is a most perfect piece of mechanism; and whilst examining it, we shall be able to infer the peculiarity of living mechanism,—that it can be preserved perfect, solely by the natural exercise

of its parts. The horse, a native of extensive plains and steppes, has a structure admirably suited to these his natural pasture grounds. When brought, however, into subjection, and running on our hard roads, his feet suffer from concussion. The value of the horse, so often impaired by lameness of the foot, has made this part an object of great interest; and I have it from the excellent professor of veterinary surgery to say that he has never demonstrated the anatomy of the horse's foot without finding something new to admire.

The weight and power of the animal require that he should have a foot in which strength and elasticity are combined. The first thing that attracts attention is the position of the bones. Had they been placed the one directly over the other, there could have been no elasticity; but on the contrary they are placed obliquely over each other, and a strong elastic ligament runs along behind them, terminating by an attachment to the lowest or coffin bone.* So essential is the obliquity of the bones

* The convexity of the bone, the elastic ligament, and the tendons behind the cannon bone, can be distinguished by the eye, and by the hand, and constitute one of the "points" of a horse; because there is so perfect a correspondence between the strength of an animal's bones, tendons, and muscles, that in those sinews the jockey sees the perfection, or the defect of the whole.

to the elasticity of the limb, that by observing the position of the pastern bones, and coffin bone, it is possible to say whether or not a horse goes easily without mounting it.

The bones of the foot of the camel rest on a soft elastic cushion. There is a texture of the same kind in the horse's foot, but it acts very differently and never comes to the ground ; nor indeed does the sole of the horse's foot bear its weight. The horny frog, the triangular projection in the hollow of the hoof, has above it this elastic frog or cushion. These are essential parts, inasmuch as receiving the weight of the animal, they press out the crust, or that part of the horny hoof which we see when the foot is on the ground. The anterior tip of this crust, or the part which last touches the ground as the foot rises, is very dense and firm, to withstand the pressure against the ground and the impulse forward : the lateral part of the crust, however, is more elastic, and on its play depends that elasticity of the foot which prevents concussion.

This crust is not consolidated with the bone called coffin bone ; for, between them there are elastic laminae. When the animal puts his foot to the ground, the weight bearing on the coffin bone, and this bone being attached by these elastic laminae to the circle of the crust, the lateral parts yield, and the weight is sustained by the

margin of the crust; the sole never touching the ground, unless it has become diseased.

Xenophon, speaking of the Persian horses, says that their grooms are careful to curry them on a pavement of round stones, that by beating their feet against a firm and irregular surface the texture of the foot may be put into exercise. It corresponds curiously with this, that our high-bred horses are subject to a disease of the foot, from which our heavy draught horses, and Flanders horses are exempt. Horses for the turf move with the foot close to the ground; no time is lost in lifting high the foot in the semicircle, the race horse being light; and the foot coming thus down gently, it wants the full play of the apparatus, whilst the heavy horse with less blood, lifts its foot in a circle and comes forcibly on the ground. Hence it may be understood how the lighter horse is subject to contractions of the foot. The bones, ligaments, and crust are out of use, the sole becomes firm as a board, the sides of the crust are permanently contracted, the parts have no longer their elastic play, and the foot striking our hard pavement suffers a shock or concussion; then comes "a fever of the foot," which is inflammation, and that goes on to its total destruction. The proof of all this is, that by paring and softening the exterior of the hoof, so as to restore its elasticity, the veterinary surgeon cures this contracted foot, unless the

inflammation has been permitted to destroy the fine apparatus entirely.

That there is a relation between the internal structure and the covering, whether it be the nail, or crust, or cloven hoof, we can hardly doubt: and an unexpected proof of this offers itself in the horse. There are some very rare instances of a horse having digital extremities. According to Suetonius, there was such an animal in the stables of Cæsar; another was in the possession of Leo X.; and Geoffroy St. Hilaire, in addition to those, says, that he has seen a horse with three toes on the fore-foot, and four on the hind-foot.* These instances of deviation in the natural structure of the bones were accompanied with a corresponding change in the coverings—the toes had nails, not hoofs.

By these examples, it is made to appear still more distinctly that there is a relation between the internal configuration of the toes and their coverings—that when there are five toes complete in their bones, they are provided with perfect nails—when two toes represent the whole, as in the cleft foot of the ruminant, there are appropriate horny coverings—and that when the bones are joined to form the pastern bones and coffin bone, there is a hoof or crust, as in the horse, couagga, zebra, and ass.

* Such a horse was not long since exhibited in Town, and at Newmarket.

In ruminants there is a cannon bone, but the foot is split into two parts, and this must add to its spring or elasticity. I am inclined to think that there is still another intention in this form ; it prevents the foot sinking in soft ground, and permits it to be more easily withdrawn. We may observe how much more easily the cow withdraws her foot from the yielding margin of a river, than the horse. The round and concave form of the horse's foot is attended with a vacuum or suction as it is withdrawn ; while the split and conical shaped hoof expands in sinking, and is easily extricated.

In the chamois and other species of the deer



The left hand figure represents the bones of the foot of the antelope ; the right, those of the rein-deer.

there is an additional toe. A sort of lesser cannon bone, with its two pasterns, supports this toe, and is joined by ligament to the larger cannon bone, so that it must have great elasticity. As a division of the flexor tendon runs into it, it must increase the spring when the animal rises from its crouching position. We see, in these sketches, that the lesser metacarpal bone, which, in the horse, entered into the joint of the "knee," as the splint-bone, is here brought down to increase the elasticity, or to expand the foot.

The two lateral toes of the hog are short, and do not touch the ground, yet they must serve to sustain the animal when the foot sinks. In the rein-deer these bones are strong and deep, and the toe, by projecting backwards, extends the foot horizontally—thus giving the animal a broader base to stand on, and adapting it to the snows of Lapland, on the principle of the snow-shoe. The systematic naturalist will call these changes in the size, number, and place of the metacarpal bones "gradations;" I see in them only new proofs of the same system of bones being applicable to every circumstance, or condition of animals, and furnishing us with other instances of *adaptation*.

I have explained why I think that the bones of the elephant's leg stand so perpendicularly over each other; there is a peculiarity also in the

bones of the foot. In the foot of the living animal we see only a round pliant mass, which, when he stands, resembles the base of a pillar, or the lower part of the trunk of a stately tree. But when we examine the bones of the foot, we find this broad base to consist of the carpus, metacarpus, and phalanges of the toes; and these bones have a very different use from what we have hitherto noticed. They are not connected with a moveable radius, and have no individual motion, as in the carnivorous animal—they merely serve to expand the foot, the base of the column, and to give it a certain elasticity.

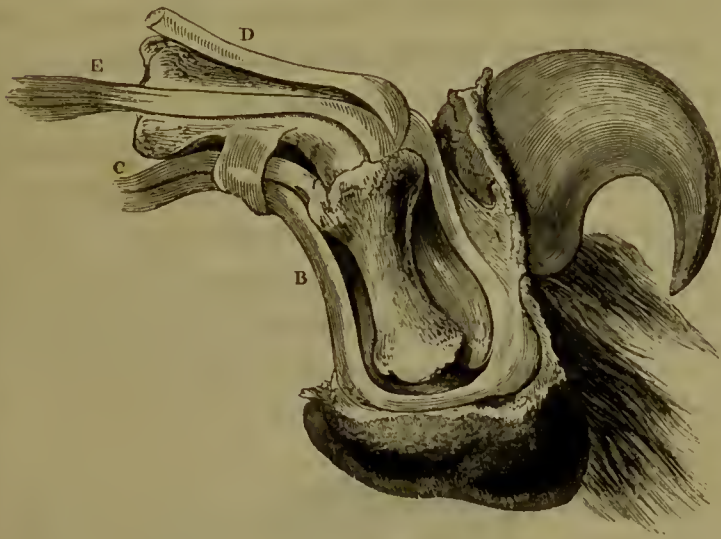
In the sketch (page 62) I have placed the bones of the foot of the camel in contrast with those of the elephant. The camel's foot having no such disproportioned weight to bear as in the elephant, lightness of motion is secured by the oblique position of its bones, as well as by the direction of the bones of the shoulder, which we have formerly noticed. In the soft texture of the camel's foot there is much to admire; for although the bottom be flat, like the sole of a shoe, yet, as we have said, there is between it and the bones and tendons a cushion so soft and elastic that the animal treads with great lightness and security. The resemblance of the foot of the ostrich to that of the camel has not escaped naturalists.

We are now treating of the last bones of the

fingers ; and let us once more see what may be done, by the study of one of these bones, to the bodying forth of the whole animal. I allude to the dissertations of the President Jefferson and Baron Cuvier on the Megalonix. We must preface this part of our subject by some remarks on the form of the claws of the lion.

The canine tribe are carnivorous, like the feline, and both have the last bones of their toes armed with a nail or claw. But their habits and their means of obtaining food are different. The first combine a keen sense of smelling with a power of continued speed ; they run down their prey. The feline order have their superiority in the fineness of their sight, accompanied with a patience, watchfulness, and stealthy movement ; they spring upon their prey, and never long pursue it. They attain their object in a few bounds, and, failing, sulkily resume their watch. When we look to the claws, we see a correspondence with those habits. The claws of the dog and wolf are coarse and strong, and bear the pressure and friction incident to a long chase. They are calculated to sustain and protect the foot. But the tiger leaps on his prey, and fastens his sharp and crooked claws in the flesh. These claws being curved and sharp, we must admire the mechanism by which they are preserved. The last bone, that which supports the claw, is placed laterally to the penultimate bone, and is so articulated with it, that an elastic

ligament (A) draws it back and raises the sharp extremity of the claw upwards. The nearer extremity of the furthest bone presses the ground, in the ordinary running of the animal,* whilst



the claw is thus retracted into a sheath. But when the tiger makes his spring and strikes, the claws are uncased by the action of the flexor tendons; and they are so sharp and strong in

* The pads in the bottom of the lion's foot cover these bones, or rather, we would say, protect them; they are soft cushions, which add to the elasticity of the foot, and must, in some degree, defend the animal in alighting from its bound. I could not comprehend how the powerful flexor muscles did not unsheathe the claws when the lion made its spring, and how they produced this effect when there was an excitement to seize and hold the prey—I made this dissection to detect the cause. The last bone of the toe is placed, in relation to the penultimate, in so peculiar a manner, being drawn back by the elastic ligament (A) beyond

the Bengal tiger, and his arm is so powerful, that they have been known to fracture a man's skull by a touch, in the act of leaping over him.

I have alluded to the observations of President Jefferson on the *Megalonix*. Having found a bone, which, by its articulating surface and general form, he recognised to be one of the bones of the phalanx of an animal of great size, he thought he could discover that it had carried a claw; and from this circumstance, he naturally enough concluded (according to the adage—*ex ungue leonem*) that it must have belonged to a carnivorous animal. He next set about cal-



culating the length of this claw, and estimating

the centre of motion of the joint, that the flexor tendon (B) acting upon it, when the animal uses his foot in mere progression, forces the nearer end, and the cushion of the toe to the ground. But when the lion strikes his prey to seize it, a more general excitement takes place in the muscles called *interossei*, and the extensors, D, E; the relative position of the two last bones is altered; the nearer end of the last bone is withdrawn from beyond the centre of motion of the joint, so that the action of the flexor tendon can now draw it forward—thus unsheathing and uncovering the claw, and preparing it to hold or to tear.

the size of the animal. He satisfied himself that in this bone, a relick of the ancient world, he had obtained a proof of the existence, during these old times, of a lion of the height of the largest ox, and an opponent fit to cope with the mastodon. But when this bone came under the scrutiny of Baron Cuvier, his perfect knowledge of anatomy enabled him to draw a different conclusion.

He first observed that there was a spine in the middle of the articulating surface of the last bone; which in this respect was unlike the form of the same bone in the feline tribe. He found no provision in this specimen of an extinct animal for the lateral attachment of the bone; which we have just shown to be necessary for its retraction. Then observing what segment of a circle this bone formed, he prolonged the line in the corresponding circumference, and showed that the claw belonging to it must have been of such great length, that it could never have been retracted to the effect of guarding an acute and sharp point. The point, therefore, could not have been raised vertically, as in the lion, so as to have permitted the animal to put the foot to the ground without blunting the instrument! Pursuing such a comparison, he rejected the idea of the bone belonging to an animal of the feline tribe at all. His attention was directed

to another order, the paresseux or sloths, which have great toes and long nails (p. 30). Their nails are folded up in a different fashion; they just enable the animal to walk; but slowly and awkwardly, somewhat in the same manner as if we were to fold our fingers on the palm of the hand, and bear upon our knuckles. On instituting a more just comparison between these bones of the ancient animal and the corresponding bones of the paresseux, he has satisfied us that the lion of the American President was an animal which scratched the ground and fed on roots.

One experiences something like relief to find that there never was such an enormous carnivorous animal as this denominated megalonix.

These unguical bones, or bones of the claws, exhibit a very remarkable correspondence with the habits and general forms of animals. Besides what we have seen in the lion, or tiger, in the dog or wolf, in the bear, and ant-eater, there is a variety, where we should least expect it, in the animals that live in woods, and climb the branches of trees. The squirrel, with claws set both ways, runs with equal facility up and down the bole, and nestles in the angles of the branches. The monkey leaps and swings himself from branch to branch, and springing parts with his hold by the hinder extremities, before

he reaches another with the anterior extremities ; he leaps the intervening space, and catches with singular precision. But the sloths do not grasp ; their fingers are like hooks, and their strength is in their arms. They do not hold, but hang to the branch. They never let go with one set of hooks, until they have caught with the other, and thus they use both hind and fore feet, whilst their bodies are pendant. Here we see, once more, the form of the extremity, the concentration of strength, and the habits of animals, conforming not merely to their haunts in the forest, but to their mode of moving and living among the branches ; all active, but in a different manner.

There have been of late deposited in our Museum in the College of Surgeons, the bones of an animal of great size ; and the examination of these gives us an opportunity of applying the principles and the mode of investigation followed by our great authority in this part of science. These remains consist of part of the head, spine, tail, pelvis, and the bones of one hinder extremity, and the scapula. Estimating the animal to which they belonged at seven feet in height, it scarcely conveys an adequate idea of its size ; for the thigh-bone is three times the diameter of that of the large elephant which is in the same collection, and the pelvis or haunch-bone, twice

the breadth of that of the same animal. Forming our opinion of it on these principles to which we have had repeated occasion to refer in this essay, and judging by the strength and prominence of the processes of these bones, the animal must have possessed great muscular power ; and directed by the same circumstances still, we can form an idea of the manner in which that muscular power was employed.

On comparing these bones with the drawings of the skeleton of the enormous animal which is preserved in the Royal Museum of Madrid, it is seen, at once, that this new acquisition is part of the remains of the great fossil animal of Paraguay, the Megatherium of Cuvier. Every observation which we are enabled to make on the extreme bones of the foot, on the scapula, and on the teeth, confirms the idea entertained by Cuvier, that it was a vegetable feeder ; and that its great strength was employed in flinging up the soil and digging for roots. Its strength seems to have been concentrated to its paws, corresponding with the provisions there for enormous nails or claws. I have heard it surmised that this animal may have sat upon its hinder extremities, and pulled down the branches of trees to feed upon. It is only its great size there that can countenance such an idea. We have not the humerus, which by its processes would have de-

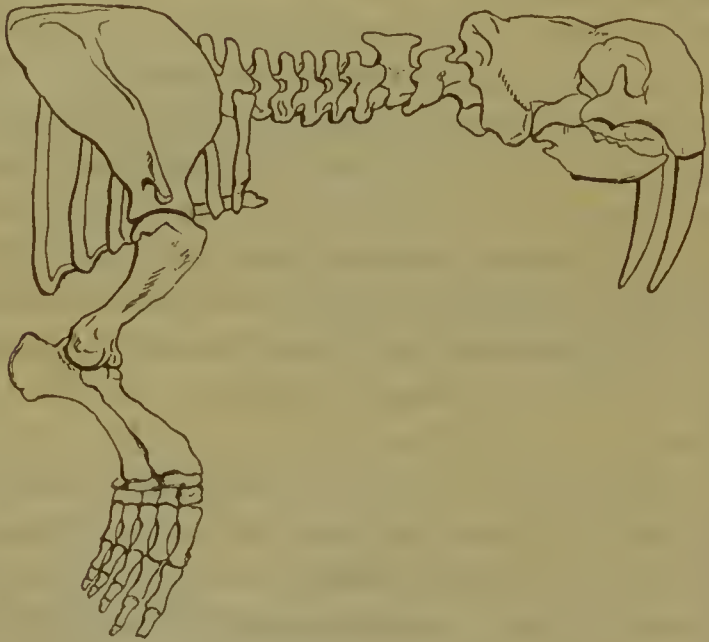
clared the classification and activity of its muscles: but we can estimate the height, breadth, and strength of the animal by the pelvis and enormous bones of the posterior extremity; while by the scapula and clavicle we can form a conception of the extent of motion of the anterior extremity, and the great power that it possessed. In short, by the osseous and muscular systems we perceive that the strength of the *Megatherium* was not so much in the body, certainly not in the jaws, but was directed rather to the extremities; and that it was given neither for rapidity of motion nor offence, but for digging.

How little was it to be expected that an alliance between anatomy, the most despised part of it, and mineralogy, was to give rise to a new science;—making a part of natural history which had been pursued in mere idleness, vaguely, and somewhat fancifully, to be henceforth studied philosophically, and by inductive reasoning. It is both interesting and instructive to find the relations thus established between departments of knowledge apparently so remote.

In the true *Amphibia*, as the *phoca* and *walrus*, we have the feet contracted, and almost enveloped in the skin, and the fingers webbed and converted into fins.

We have sketched here the bones of the *morse*, or *walrus*, and they are remarkably com-

plete, if we consider the peculiar appearance of the feet in the living animal. The bones are

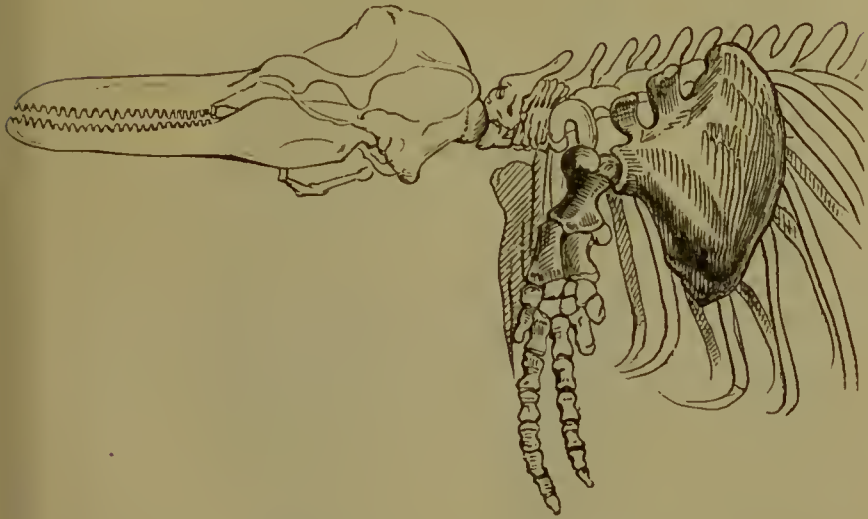


accommodated to be an instrument for swimming; for these animals live in the water, and come to land only to suckle their young, or to bask in the sun; and out of the water they are the most unwieldy and helpless of all animals which breathe.

In the Cetacea, for example, in the whales, we have mammalia unprovided with hind feet. The scapula is large, the humerus very short, and the bones of the fore-arm and hand flattened

and confined in membranes which convert them into a fin. These animals live in the water, but they must rise to the surface to breathe.

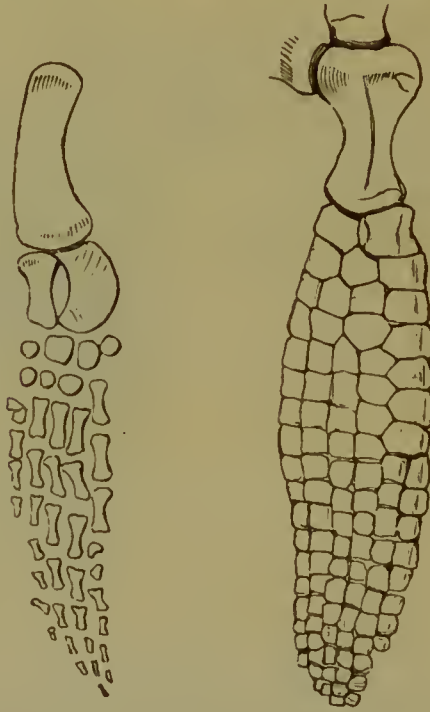
I need not say that in the dolphin we recog-



nise the bones of the anterior extremity, only a little further removed from the forms which we have hitherto been contemplating. The seal and morse raise themselves out of the water and lie on the rocks; but the different species of the dolphin continue always in the water; the extremity is now a fin or an oar, and those who have seen the porpoise or the pelloch in a stormy sea, must acknowledge how complete the apparatus is, through which they enjoy their element.

The last examples I select, shall be from the ancient world.*

These figures are taken from specimens, in

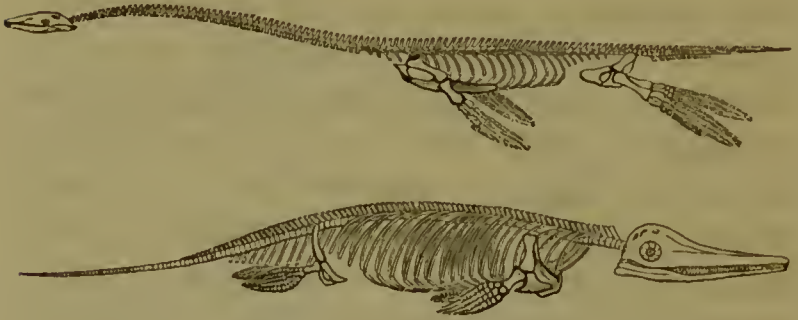


* The figure to the left is the anterior extremity of the Plesiosaurus; to the right, that of the Ichthyosaurus. In these paddles we see the intermediate changes from the foot of animals to the fin of the fish—from the walrus, dolphin, turtle, to the plesiosaurus, and ichthyosaurus—where we no longer find the phalanges or attempt to count the bones; and where they become irregular polygons or trapezoids—less like phalanges than the radii of the fins of a fish. In fishes the anterior extremity is recognised in the thoracic fin; and we may even discover the prototypes of the scapula and the bones of the arm connected with it. I know not what the naturalist, who likes to note the gradual decrease of the elementary parts, makes of these hun-

the College of Surgeons, of fossil animals of singular structure, between the crocodile and the fish. They are in a calcareous rock, and the skeletons are entire, but crushed, and a good deal disfigured. Here are the extremities or paddles, consisting of a multitude of bones articulated; and among these we still discover the humerus, radius and ulna, and bones of the carpus and fingers. No fault is to be found with the construction of these instruments; they are suited to their offices, and no bone is superfluous, or misplaced, or imperfect. The ichtyosaurus and plesiosarus (the animals which offer these specimens) inhabited the sea; their remains are found low in the lias deposit; great changes have been wrought on the land and on the deep since they existed; and the race of animals, the structure of whose extremities we have been engaged in examining, was not then in being. When we discover the same series of bones in the animals of the old world as there is in those now alive, we admit the existence of the same system; and we must necessarily acknowledge the progressive developement of that system, through a period of time incalculably remote; even if, instead of our days and years, referable to history, each day were as a thou-

dred bones of the paddle or of the fin; where there is an increase of the number, whilst, relatively speaking, there is a defect in the form and motion, of the parts.

sand years, or we were to make our estimate by the records of the revolutions which have left their traces on the globe itself.*



I have now given, I hope, sufficient examples of the changes in the bones of the anterior extremity, which suit them to every possible variety of use. After a little attention to the form of the bones of the human hand, I shall take up another division of my subject.

In this sketch we have the bones of the paw of the adult Chimpanzee, from Borneo; and the



* The wood-cuts on this page give some idea of the forms of the skeletons of the ichthyosaurus and plesiosaurus restored by the Rev. Mr. Conybeare.

remarkable peculiarity as distinguishable from the human hand, is the smallness of the thumb ; it extends no further than to the root of the fingers. On the length, strength, free lateral motion, and perfect mobility of the thumb, depends the power of the human hand. The thumb is called *pollex*, because of its strength ; and that strength is necessary to the power of the hand, being equal to that of all the fingers. Without the fleshy ball of the thumb, the power of the fingers would avail nothing ; and accordingly the large ball, formed by the muscles of the thumb, is the distinguishing character of the human hand, and especially of that of an expert workman.*

The loss of the thumb almost amounts to the loss of the hand, and were it to happen in both hands, it would reduce a man to a miserable dependence : or as Adoni-bezek said of the threescore and ten kings, the thumbs of whose hands and of whose feet he had cut off, “ they gather their meat under my table.”

In a French book, intended to teach young people philosophy, the pupil asks why the fingers are not of equal length ? The form of the argument reminds us of the difficulty of putting natural questions—the fault of books of

* Albinus characterises the thumb as the lesser hand, the assistant of the greater—*manus parva, majori adjutrix*.

dialogue. However, the master makes the scholar grasp a ball of ivory, to shew him that the points of the fingers are then equal! It would have been better had he closed the fingers upon the palm, and then have asked whether or not they corresponded. This difference in the length of the fingers serves a thousand purposes, adapting the hand and fingers, as in holding a rod, a switch, a sword, a hammer, a pen, or pencil, engraving tool, &c., in all which, a secure hold and freedom of motion are admirably combined. But we must defer this part of our subject until we have shewn the application of the muscles to the bones, and the appropriate structure of the ends of the fingers to feeling.

In conclusion,—what says Ray,—“ Some animals have horns, some have hoofs, some teeth, some talons, some claws, some spurs and beaks: man hath none of all these, but is weak and feeble, and sent unarmed into the world—Why, a hand, with reason to use it, supplies the use of all these.”

In taking leave of this part of our subject, let us mark the importance of these comparative views of anatomy to the science of Geology. It has been ingeniously and quaintly said that the organized remains imbedded in the rocks, are as the medals struck in commemoration of the great revolutions which the earth has under-

gone. Every one must have seen that the crust of the earth is formed in strata or layers: and very slight consideration leads also to the belief that it has been subject to great convulsions as well as to successive deposits or formations. Each of these layers is to a certain degree distinct in the chemical composition, in the fracture and external character, but chiefly in the nature of the animal remains which are buried in it.

Of these strata, some are distinguished by containing the bones of large animals: and it is by attending to the forms and processes of these bones, that by far the most interesting conclusions, in the whole range of this new science, may be drawn. A very short account of the successive deposits, forming the different strata, will serve to illustrate the importance of the anatomy of the animals which have the true bony skeleton, to the geologist. The last grand revolution has formed a surface to the earth, in which strata, of every condition, have been exposed. And indeed, we might say that such exposure, by laying open the riches of the earth as well as furnishing the mixed soil for vegetation, has been the end of this revolution. At all events, the variety of objects disclosed on the surface tends to confound the enquirer: and, therefore, we must shortly recapitulate what has been discovered by the investigations of scientific and ingenious men in our time.

Without hazarding conjectures on the eleva-

tion or production of the "primitive rocks," we have at present only to notice the stratifications superimposed. Of these, the most striking and the most difficult to reconcile to theory, are the strata of coal: but we pass over them as containing no animal remains in which the knowledge of the anatomy of the vertebrata can be of use. On the supposition that these beds of coal are vegetable productions, we might expect to find the remains of terrestrial animals within them: but it is conjectured that the vegetables which compose them, were not such as we are now familiar with, and that the land where they grew did not form a suitable habitation for animals corresponding with those of the present epoch.

Above the beds of coal, are strata, regular, well ascertained, and interesting as indicating the presence of the coal beneath. The next remarkable stratifications above them come to be connected with our subject; because they contain the remains of gigantic animals, with a regular skeleton on the system of the vertebrata.

Some of the oviparous quadrupeds, here alluded to, are estimated to have been eighty feet in length.* But although their skeletons were

* The *Megalosaurus*, discovered by Professor Buckland in Oxfordshire, is supposed to have been about seventy feet in length. The *Iguanodon*, an herbivorous masticating reptile, first discovered by Mr. Mantell in the Wealden beds, in Sussex, is computed to have been seventy or eighty feet in its entire length, its tail being fifty feet, its height nine feet, its hind foot six feet and a half, and its body about the same thickness as the elephant's.

formed on the plan, if we may thus express it, of quadrupeds, the extremities of many of them were more paddles than feet:* and we conclude that they were capable of dragging their huge bulk on the land, because the structure of their skeletons proves that they were oviparous and breathed the atmosphere. Some of them had a conformation in their extremities, resembling that of our present oviparous quadrupeds, to enable them to walk or crawl on slimy ground; and judging by the habits of these, as the crocodile, gaval, alligator, and cayman, certain species of which were among them, they lived in still water, with muddy bottom, retreating under the mud, and projecting their snouts between the aquatic plants, to breathe: and they must have been prolific to an extraordinary degree, as they had not their enemies, the vulture and the ichneumon, which destroy multitudes of the eggs of these creatures of the present day. Others seem to have had their skins extended on their anterior extremities,† if not to provide a power of flight, at least to allow them to drop in safety from the elevations which they might have crept to.

The *Hylæosaurus*, the last discovered of these huge animals in the same beds, and supposed by Mr. Mantell to have been a reptile intermediate between the crocodiles and the lizards, is estimated to have been about thirty feet in length.

* See page 114, and also the Appendix.

† The Pterodactyles, see page 83.

Stratified rocks, composed of lime, clay, or sandstone, under the denominations of lias, oolite, Wealden or Sussex beds, Stones-field slate, &c., are visible in the south of England, and extend to many parts of Europe: and these strata contain a great variety of those oviparous reptiles. There is every appearance of these deposits having been submerged and deeply buried in the ocean: from which thick beds of chalk have been deposited over them. Above the chalk, again, are to be found a series of stratified rocks, implying a new condition.

The lowest layer of this "tertiary formation" is sometimes called the product of the Palæotherian period: during its deposit, animals of a distinct creation, the species of which cannot be identified with those imbedded in the strata under the chalk, are found. Here, for the first time, there was a condition of the earth suited for terrestrial animals, which retired under the shade of woods and gave suck, the mammalia. Yet it is remarkable, that in this, the lowest stratification of the tertiary formation, the animals of the class mammalia only approached to the condition of those which are now alive: we find the remains only of such as are now extinct.

When the layers forming the tertiary beds are examined in succession upwards, they are still distinguishable by their organic products: and

as we approach the surface, if theory has not quite deceived us, there are fewer remains of the extinct quadrupeds, and more numerous specimens of such as now inhabit the earth. We find in the different strata the bones of the mammoth, the megatherium, the elephant, the tapir, the rhinoceros, the hippopotamus, the stag, the ox, the horse, and with them the skeletons of their natural enemies of the feline tribe, and the bear and the hyæna, the bones of which prove them to have been of greater strength and size than those that are now alive.

Over the earth's surface, as thus formed, there are evidences that a deluge has swept with inconceivable power, brushing off the superficial strata, rolling immense rocks, and depositing the debris, so as to fill chasms, form new accumulations, and once more to change the whole character of the earth's surface.* It was then that it assumed its present confines of land and sea, and that the valleys and the courses of rivers were determined. Out of these convulsions and successive revolutions has come that condition of the world which we now enjoy, and, as I shall have occasion to repeat, no previous state of the earth's surface would have been suitable to our constitution.

The waters as they flow to the ocean, and as

* See *Reliquiæ Diluvianæ*, by Professor Buckland.

they are there met by tides and currents, accumulate mud, gravel, and the remains of animals of the species which now exist: and the deposits which have thus taken place are distinguished from those produced by the grand revolutions which preceded, by the term 'alluvium.'

My admiration of the labours of our geologists partakes of a feeling of gratitude. But yet there is something in the subject which leads the devoted student to be too ambitious, and to frame theories almost too comprehensive. It is not enough for the geologist to say that, after all, the changes on the earth's surface which he describes as having taken place, are not greater, in comparison with the size of the earth, than the cracks in the varnish are to the globe that stands on the table. But it has been part of our object to show that the features of our globe, and the phenomena around us, are suited, and intended, to excite the faculties and imagination. Accordingly, when the mineralogist extends his survey from the mountains over extensive plains, and looks down into the ravines and valleys, and persuades himself that he can say when and how they have been formed, he is tempted to indulge in an enthusiasm which can have its merit only with the poet.

Wonderful improvements have indeed been made in this science by our countrymen who have associated themselves for this purpose.

Buckland, Conybeare, and Mantell, are especially distinguished for the discovery of these large Saurian reptiles; whilst other geologists have exerted their genius and industry with equal effect in different departments. But it is in contemplating the labours of Cuvier, that we have the earliest and the best proofs of the importance of comparative anatomy, in giving extraordinary interest to this science. In him there was combined an attention to minute things and a power of generalizing, highly characteristic of genius. Years had been passed in accumulating the animal remains from the quarries round Paris; and out of this heap, which lay as confused as if the bones had been washed to his feet by a torrent, he was enabled, by following the principle which the early part of this chapter has shown to prevail—the co-existence of the parts of the skeleton—to put together the separate members, to build up the skeletons of extinct animals anew, and to present them to us with a precision which we could only have expected from the dissection of the recent animals.

CHAPTER IV.

Of the Muscles of the Arm and Hand—their Vital Action—their Mechanical Adaptation to the Motions of the Hand and Fingers—Form of the Human Hand.

THE muscle of the body is that fleshy part, with which every one is familiar. It consists of fibres which lie parallel to each other. This fibrous, or filamentous part, has a living endowment, a power of contraction and relaxation, termed irritability. A single muscle is formed of some millions of these fibres combined together, having the same point of attachment or origin, and concentrating in a rope or tendon, which is fixed to a moveable part, called its insertion. We may demonstrate upwards of fifty muscles of the arm and hand, all of which must consent to the simplest action; but this gives an imperfect view of the extent of the relation of parts which is necessary to every act of volition. We are most sensible of this combination in the muscles, when inflammation has seized any of the great joints of the body: for even when in bed, every motion of an extremity gives pain, through the necessity

of a corresponding movement in the trunk. When we stand, we cannot raise or extend the arm without a new position of the body, and a poising of it, through the action of a hundred muscles.

ON THE ACTION OF THE MUSCLES OF THE ARM.

We shall consider this subject under two heads; in the first, we shall give examples of the living property of the muscles; and then of the mechanical contrivances, in their form and application. In all that regards the muscles, we see the most bountiful supply of power commensurate to the object, but never any thing in the least degree superabundant. If the limb is to be moved by bringing a muscle, or a set of muscles into action, the power is not given in that excess which would enable them to overcome their opponents; but the property of action is withdrawn from the opponents; they become relaxed, and the muscles, which are in a state of contraction, perform their office with comparative ease. A stationary condition of the limb results from a balanced but regulated action of all the muscles; which condition may be called their tone. If, in an experiment, a weight be attached to the tendon of an extensor muscle, it will draw out that muscle to a certain degree, until its tone or permanent state resists the weight: but if the

flexor muscle be now excited, this being the natural opponent of the extensor, the weight will fall, by the relaxation of the extensor. So that the motion of a limb implies an active state or a change in both classes of muscles, the one to contract, the other to relax; and the will influences both classes. Were it not so regulated, instead of the natural, easy, and elegant motions of the frame, the attempt at action would exhibit the body convulsed, or, as the physicians term it, in clonic spasms. The similitude of the two sawyers, mentioned by Paley, gives but an imperfect idea of the adjustment of the two classes of muscles. When two men are sawing a log of wood, they pull alternately, and when the one is pulling, the other resigns all exertion. But this is not the condition of the muscles—the relaxing muscle does not give up all effort, like a loose rope, but is controlled in its yielding, with as fine a sense or adjustment, as is the action of the contracting muscles. Nothing appears to us more simple than raising the arm, or pointing with the finger; yet in that single act, not only are innumerable muscles put into activity, and as many thrown out of action, but both the relaxing and the contracting muscles are controlled or adjusted with the utmost precision though in opposite states and under the same act of volition.

By such considerations, we are prepared to admire the faculty which shall combine a hun-

dred muscles so as to produce a change of posture or action of the body ; and we now perceive that the power taken from one class of our muscles, may be considered as if it were bestowed on the other ; so that the property of life, which we call the irritability, or action of a muscle, is upon the whole, less exhausted than would be the case on any other supposition.

As to the second head, our demonstration is of an easier kind. We have said that nature bestows abundantly, but not superfluously ; a truth evinced in the arrangement of the muscles. All the muscles of the limbs have their fibres running in an oblique direction,—thus A. being the tendinous origin of a muscle, and B. the tendinous insertion, the fleshy fibres run obliquely between these two tendons.



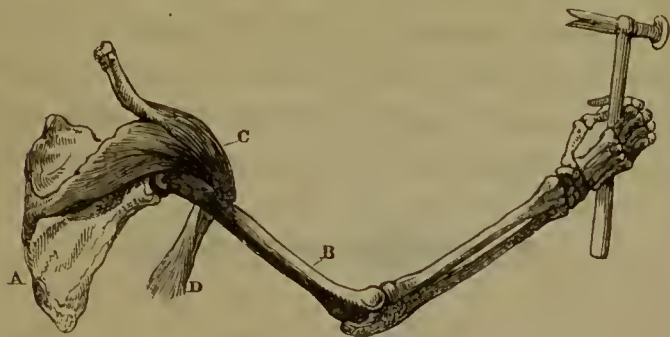
The fibre acting thus obliquely loses power, but gains the property of pulling what is attached to its further extremity through a greater space, while it contracts ; and consequently the velocity is increased. This mechanical arrangement is intelligible on the law, that velocity of motion through space, is equal to power or weight. Here in the muscle, there is a resignation of power to obtain velocity of motion.

The same effect is produced by the manner in which the tendons of the muscles run over the joints. They would act more powerfully, if they went in a straight line to the toes or tips of the fingers: but by being laced down in sheaths, they move the toes and fingers with a velocity proportioned to their loss of power.

Let us see how far this corresponds with other mechanical contrivances. A certain power of wind or water being obtained, the machinery is moved; but it is desired to give a blow, with a velocity far greater than the motion of the water or the turning of the wheels. For this purpose a fly-wheel is put on, the spokes of which may be considered as long levers. The wheel moves very slowly, at first; but being once in motion, each impulse accelerates it with more and more facility; at length, it acquires a rapidity, and a centrifugal force which nothing can equal in its effects, but the explosion of gunpowder. The mechanist not having calculated the power of accelerated motion in a heavy wheel, has seen his machinery split and burst up, and the walls of the house blown out as by the bursting of a bomb-shell. A body at rest receives an impulse from another, which puts it into motion—it receives a second blow; now this second blow has much greater effect than the first—for the power of the first was exhausted in changing the body from a state of rest to that of motion—but being in motion when it receives the second

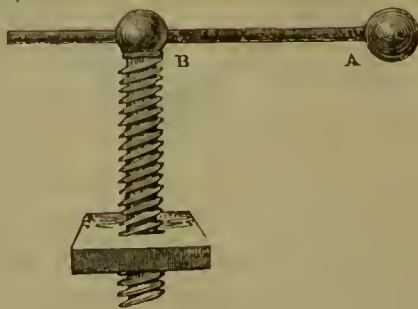
blow, the whole power is bestowed on the acceleration of its motion ; and so on, by the third and fourth blows, until the body moves with a velocity, equal to that of the body from which the impulse is originally given. The slight blow given to a boy's hoop is sufficient to keep it running ; and just so the fly-wheel of a machine is kept in rapid action by a succession of impulses, each of which would hardly put it in motion. If we attempt to stop the wheel, it will give a blow in which a hundred lesser impulses are combined and multiplied.

There is, in the machinery of the animal body, in a lesser degree, the same interchange of velocity and force. When a man strikes with a hammer, the muscle near the shoulder,*



* A. The scapula, or shoulder blade ; B. the humerus, or arm-bone ; C. the deltoid muscle of the shoulder, arising from the shoulder-blade and clavicle, and inserted into the arm-bone ; D. a muscle which draws the arm down, as in striking with a sword or hammer.

c., acts upon the humerus, B., in raising the extended lever of the arm and hammer, with every possible disadvantage, seeing that it is inserted or attached so near the centre of motion in the shoulder joint. But the loss of power is restored in another form. What the muscle D. loses by the mode of its insertion, is made up in the velocity communicated to the hammer; for in descending through a large space, it accumulates velocity, and velocity is equal to force. The advantage of the rapid descent of a heavy body is, that a smart blow is given, and an effect produced which the combined power of all the muscles, without this mechanical distribution of force, could not accomplish. This is, in truth, similar to the operation of the fly wheel, by which the gradual motion of an engine is accumulated in a point of time, and a blow is struck capable of crushing or of stamping a piece of gold or silver. In what respect does the mechanism of the arm differ from the engine with which the printer throws off his sheet?



Here is a lever with a heavy ball at the end ; in

proportion to its weight, it is difficult to be put in motion. The printer, therefore, takes hold of the lever near the ball, at *A*. Were he to continue pulling at that part of the lever, he would give to the ball no more velocity than that of his hand; but having put the ball into motion, he slips his hand down the lever to *B*. He could not have moved the weight, had he applied his hand here at first; but it being now in motion, the whole strength of his arm is given to the lever at *B*., whilst the velocity of the great weight at the further end is accelerated. Thus the weight and the velocity being combined, the impulse given to the screw is much greater than if he had continued to pull upon the further end of the lever at *A*.

If we now turn our eye to the diagram (page 129), we shall understand that the muscle *c*. raises the long lever of the arm at a disadvantage, or very slowly; but the arm being moved, that motion is rapidly increased by each successive impulse from the muscle; and, of course, the velocity at the further extremity is more rapid than at the insertion of the tendon.

Again, if we consider the action of the muscle *d*. in pulling down the arm, as in giving a back stroke with the sword, we have the combination of two powers,—weight and muscular effort. When the hammer descends, the rapidity is increased by the mere effect of gravity; but

when the action of the muscle is conjoined, the two forces, progressively increasing, greatly augment the velocity of the descent.

The same interchange of power for velocity, which takes place in the arm, adapts a man's hand and fingers to a thousand arts, requiring quick or lively motions. The fingers of a lady, playing on the pianoforte, or of the compositor with his types, are instances of the advantage gained by this sacrifice of force for velocity of movement. The spring of the foot and toe is bestowed in the same manner, and gives elasticity and rapidity in running, dancing, and leaping.

The motions of the fingers do not result merely from the action of the large muscles which lie on the fore-arm : these are for the more powerful efforts ; but in the palm of the hand, and between the metacarpal bones, there are small muscles, (*lumbricales* and *interossei*) which perform the finer motions, — expanding the fingers, and moving them in every direction with quickness and delicacy. These small muscles, attached to the near extremities of the bones of the fingers where they form the first joint, being inserted near the centre of motion, move the ends of the fingers with very great velocity. They are the organs which give the hand the power of spinning, weaving, engraving ; and as they produce the quick motions of the musician's fingers they are called by the anatomists *fidicinales*.

But there is another use for certain small muscles in the hand. The combined strength of all the muscles, in grasping, must be very great: indeed, the power is exhibited when we see a sailor hanging by a rope, and raising his whole body with one arm. What then must be the pressure upon the hand? It would be too much for the texture even of bones and tendons, and certainly, for the blood vessels and nerves, were not the palms of the hands, the inside of the fingers and their tips, guarded by cushions. The elastic pad in the foot of the horse and camel is not a whit more appropriate than the fine elastic texture of the hand. To add to this purely passive defence there is a muscle, which runs across the palm, and more especially supports the cushion on the inner or ulnar edge: it acts powerfully as we grasp; and it is this muscle which, raising the edge of the palm, hollows it, and adapts it to lave water, forming the cup of Diogenes.

Whilst the cushions on the ends of the fingers defend them in the powerful actions of the hand, we shall presently see that they are useful in subservience to the nerves of touch; conferring a power of receiving impressions, which the utmost delicacy of the nerves themselves could not bestow.

After the many illustrations from mechanics which we have offered, the muscular power itself

must be a subject of surprise and admiration. Gravity, the running of water, the expansion and condensation of steam, the production of gases, the spring or elasticity of material, or all these combined, could not have answered the varied offices performed by this one property of life possessed by the muscles. The irritable and contractile fibre, matter which, chemically considered, does not differ from the fibrine of the blood, being endowed with this property of contraction, and adapted with "mechanical ingenuity," fulfils a thousand distinct purposes, in volition, breathing, speaking, in digestion, assimilation, circulation; and in all these it is modified to the wants and condition of every class of animals.

From what the reader already understands of the conformity which subsists among all the parts of an animal body, he will readily comprehend that there is a perfect relation between the bones and the muscles: that as the bones change, and exhibit a variety in their size, relative position, and articulations, so there is an adaptation of the muscles. Accordingly, we sometimes find the muscles separated into smaller, and sometimes consolidated into more powerful masses.

The demonstration to the anatomical student of the muscles of the human hand and arm, becomes the test of his master's perfection as a

teacher. Nothing is more uninteresting, tedious, and difficult to attend to, than the demonstration of the muscles of the arm, when they are taken successively, as they present themselves; but when they are taught with lucid arrangement, according to the motions performed by them, it is positively agreeable to find how much interest may be given to the subject.

It would be foreign to the object of this work to introduce such demonstrations here.

Yet it is very remarkable that the muscles of the arm and hand should resemble so closely the muscles of the fore extremity of the lion, for example. I have added a sketch of the muscles of the lion's fore leg and paw; in which we see that the shape bears a great resemblance to the fore-arm of man. The flexors, extensors, pronators, and supinators are, in the brute, exactly in the same place, and bear all the relations which the student of anatomy is taught to observe with so much interest in the human arm. This example is sufficient to show how accurately the comparative anatomy of the muscles conforms to that of the bones; and that in proportion as the bones of the extremity resemble, in shape and power of motion, those of the human arm, so do the muscles—another proof of the great extent of the system of relations established in the animal frame.

There is one circumstance more which should

not be omitted in the comparative anatomy of these muscles, as it exhibits another instance of



conformity in their structure to the offices which they have to perform. We have just stated that

the power of contraction is a vital property. The continued action of a muscle, therefore, exhausts the vitality; and to support that action, when it is inordinate, there must be a more than usual provision for the supply of this living power, viz:—a means of increasing or maintaining the circulation of the blood, which is the source of all vital power.

In the *loris tardigradus** it has been observed that the axillary and femoral arteries, the great arteries of the anterior and posterior extremities, have this peculiarity—that the main vessel is sub-divided into a number of equal-sized cylinders, which again unite to form a single trunk previous to the distribution, of its branches to the muscles.† It has been argued that this peculiarity, as it produces a retardation of the blood, is adapted to the slow motion of the animal. I believe it to be a provision for long continued action; because the animals which possess it, are not more remarkable for the slowness of their progression than for the tenacity of their hold: the extremities are long and the muscles powerful, either for sustaining the animal by grasping the branches of trees, or for digging; but surely the strength of the muscles cannot be produced by retardation of the cir-

* See the Appendix, Division I. Quadrumana.

† There is some doubt as to the reunion of the vessels.

ulation, on the principle, universally admitted, that the expenditure of arterial blood is in proportion to the vital force employed.

Buffon tried to make a dog amphibious, by immersing the puppy before it had breathed, in tepid water. One of our own physiologists thought it possible to make a tardigrade animal out of a vivacious spaniel by putting ligatures upon the arteries which go to its limbs, and forcing the blood to take a circuitous course, by numerous channels, to the muscles. We need hardly say that these experiments failed. They were undertaken in a misconception of the living properties; which are more finely adjusted than any thing to be seen in the mere mechanism of the body. Every muscle of the body has its prescribed mode of action, from the unwearied irritability of the heart to the effort of the muscle which guides the pen. Some are ever in action with but short intervals; others act in regular succession: some are under the will, others withdrawn from it; some act quickly as the heart, others act slowly as the stomach; but these are original endowments, and do not result from the force or languor of the circulation of the part.

Were the arteries of the living body like rigid tubes, and the laws of the circulation the same as those of hydraulics, a subdivided and tortuous artery would certainly be the means of retarding the circulation. But it is impossible to believe

that the circulation of the blood can be performed according to the laws which govern the flow of water in dead tubes. The artery is dilatable; it contracts with a vital force; and both the dilatability and the contractility of arteries are subject to the influence of the living principle. When, therefore, the artery of a limb is divided into four or five vessels, and these are tortuous, as in the sloths, the result is a greater capacity of dilatation, and a greater power of contraction; and these being vital operations, are subject to be influenced and adjusted according to the necessity for the increase or diminution of the circulation. If such a peculiarity in the form of the vessels in the extremities of these animals, retards the blood, it can only be during repose; for, on excitement, so far from retarding, it must bestow a remarkable power of acceleration. I conclude, therefore, that this variety of distribution in the arteries is a provision for occasional great activity in the muscles of the limb, and for forcing the blood into contact with the fibres, notwithstanding their long continued action and rigidity.

We have seen, in the preceding chapter, that the same organ, which moves at one time as slowly as the hand of a watch, at another acts with extreme rapidity: consequently, we can not admit the inference that the tortuous and subdivided artery is a provision for languid motions.

In speaking of the arteries which go to the hand, it may be expected that we should touch on a subject, which has been formerly a good deal discussed, whether the properties of the right hand, in comparison with those of the left, depend on the course of the arteries to it: for it is affirmed that the trunk of the artery going to the right arm, passes off from the heart so as to admit the blood directly and more forcibly into the small vessels of the arm. This is assigning a cause which is unequal to the effect, and presenting, altogether, too confined a view of the subject: it is a participation in the common error of seeking in the mechanism the cause of phenomena which have a deeper source.

For the conveniences of life, and to make us prompt and dexterous, it is pretty evident that there ought to be no hesitation which hand is to be used, or which foot is to be put forward; nor is there, in fact, any such indecision. Is this taught, or have we this readiness given to us by nature? It must be observed, at the same time, that there is a distinction in the whole right side of the body, and that the left side is not only the weaker, in regard to muscular strength, but also in its vital or constitutional properties. The developement of the organs of action and motion is greatest upon the right side, as may at any time be ascertained by measurement, or the testimony of the tailor or shoemaker; certainly,

this superiority may be said to result from the more frequent exertion of the right hand ; but the peculiarity extends to the constitution also ; and disease attacks the left extremities more frequently than the right. In opera dancers, we may see that the most difficult feats are performed by the right foot. But their preparatory exercises better evince the natural weakness of the left limb, since these performers are made to give double practice to this limb, in order to avoid awkwardness in the public exhibition ; for if these exercises be neglected, an ungraceful preference will be given to the right side. In walking behind a person, it is very seldom that we see an equalized motion of the body ; and if we look to the left foot, we shall find that the tread is not so firm upon it, that the toe is not so much turned out as in the right, and that a greater push is made with it. From the peculiar form of woman, and the elasticity of her step resulting more from the motion of the ankle than of the haunches, the defect of the left foot when it exists, is more apparent in her gait. No boy hops upon his left foot, unless he be left handed. The horseman puts the left foot in the stirrup and springs from the right. We think we may conclude, that every thing being adapted, in the conveniences of life, to the right hand, as for example the direction of the worm of the screw or of the cutting end of the

augur, is not arbitrary, but is related to a natural endowment of the body. He who is left handed is most sensible to the advantages of this adaptation, from the opening of the parlour door to the opening of a pen-knife. On the whole, the preference of the right hand is not the effect of habit, but is a natural provision, and is bestowed for a very obvious purpose: and the property does not depend on the peculiar distribution of the arteries of the arm—but the preference is given to the right foot, as well as to the right hand.

CHAPTER V.

THE SUBSTITUTION OF OTHER ORGANS FOR THE
HAND.

AFTER having examined the manner in which one instrument, the hand, is modified and adapted to a variety of purposes in different animals, there remains only this mode of elucidation—that we contrast it with its imperfect substitutes in other creatures. I might, indeed, have shown in the insect tribes the most curious examples of instruments for similar purposes with the hand and fingers of man; but I have intentionally confined this inquiry to the higher classes of animals.

The habits of some fishes require that they should cling firmly to the rocks or to whatever presents to them. Their locomotive powers are perfect; but how are they to become stationary in the tide or the stream? I have often thought it wonderful that the salmon or the trout, for example, should keep its place, night and day, in the rapid current. In the sea, there are some fishes especially provided with means of clinging to the rocks. The lump-fish, *cyclopterus lumpus*,

fastens itself by an apparatus which is on the lower part of its body. The sucking fish, *remora*, has a similar provision on its back. It attaches itself to the surface of the shark and to whatever is afloat; and, of course, to the bottoms of ships. The ancients believed it capable of stopping a ship under sail, and Pliny, therefore, called it *remora*. We must admire the means by which these fishes retain their proper position in the water, without clinging by their fins or teeth, and while they are free for such efforts as may enable them* to seize their food. The apparatus by which they attach themselves resembles a boy's sucker: the organ being pressed against the surface to which the creature is to be fixed, the centre is drawn by muscles in the same manner that the sucker is drawn with the cord, and thus a vacuum is made.

Dr. Shaw tells us, that on throwing a fish of

* In the Mollusca and Zoophytes we find many instances of the animal holding on against the force of tide or current. The Actiniæ fix themselves to rocks and shells; and some, as the sea carnation, hang suspended from the lower surface of projecting rocks, resembling the calyx of a flower. By the elongation of their tentacula, they expand and blow out like a flower; but instead of petals, these are prehensile instruments by which they draw whatever food floats near them into their stomachs. The byssus of the muscle is a set of filaments which retains the shell at anchor, and prevents it drifting or rolling with the tide: these filaments are the secretion of a gland; and whilst they are fixed to the rock, the gland retains the hold at their other ends. The shell of the oyster is itself cemented to the rock.

the species cyclopterus lumpus into a pail of water, it fixed itself so firmly to the bottom, that by taking hold of the tail, he lifted up the pail, although it contained some gallons of water.

In the cuttle-fish we see a modification of this apparatus: the suckers are ranged along their feelers or arms, and become instruments of prehension and of locomotion. They are capable of being turned in all directions, either to fix the animal or to drag it from place to place. In the Indian seas, these creatures become truly terrific from the length of their arms, which extend to eight or nine fathoms, and from the firmness with which they cling.



There is another fish, which from its name we should expect to perform strange antics; it is called harlequin angler.* Its appearance is

* *Lophius Histrion*, from a Greek word that has reference to the process which floats from the head, like a streamer or pennant.

grotesque and singular; the pectoral fins resemble short arms, and are palmated at their tips.* M. Renau, in his history of fishes, affirms that he knew an individual of this species; and the expression is not so incorrect, since he saw it for three days out of the water, walking about the house in the manner of a dog. The circumstance of its walking out of the water has some interest, as showing relations between organs which are apparently the least connected. The fact of this fish living out of the water is doubted; but the form of its branchial organs, or organs for breathing, inclines me to believe it; and its habits require such a provision. In this genus, the operculum, which covers the gills, does not open to let the respired water pass off freely behind, as in most fishes; but the water is discharged by a small aperture which, in Mr. Owen's opinion, is capable of being closed by a sphincter muscle. The cavities in which the branchiæ lie are large, and this is, indeed, partly the reason of the monstrous head of this fish. Thus, it has not only its fins converted into feet, but its gill-covers into pouches, capable of containing water, and of permitting the function of the branchiæ to proceed when the water is retired; that is, when it

* These fins have two bones in them like the radius and ulna; but Cuvier says that they are more strictly bones of the carpus.

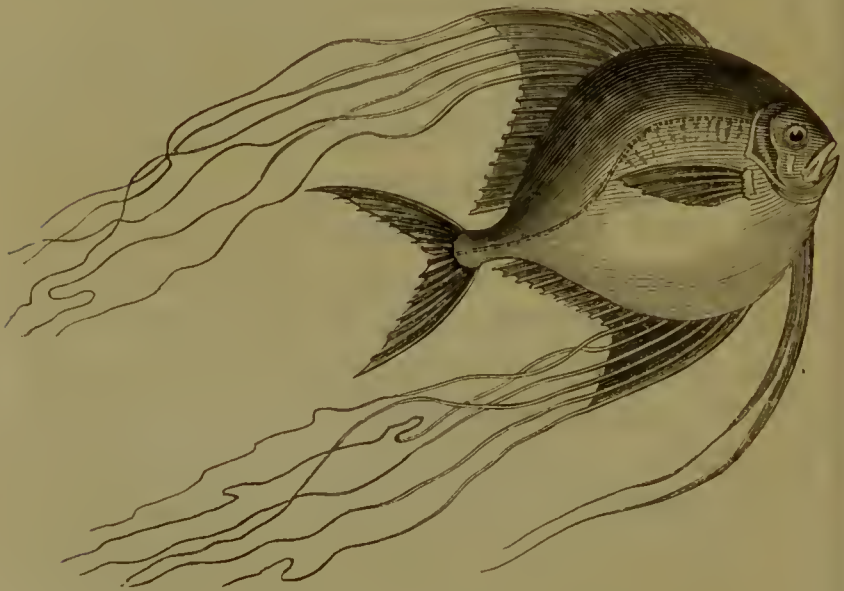
lies in mud, or shallow pools ; for in such situations does the *lophius* find its food ; and it angles for it in a very curious manner.

But there are other fishes that move out of the water on dry land, and even ascend trees, without being carried there by floods. The *perca scandens*, by means of the spines of its gill-covers, and the spinous rays of its fins, climbs trees ; so that Dr. Shaw calls it the climbing fish.*

All creatures which have their skins protected, whether by feathers, or shells, or scales, have an exquisite sense of touch in their mouth, or in the appendages which hang from it. Fishes have *cirri* which hang from their mouth ; and these are equivalent to the feelers or tentacula of insects and crustacea. The fishing lines of the *lophius piscatorius* are examples of these processes : and Pliny relates that this frog-like fish, hiding in the mud, leaves the extremities of these filaments visible ; which, from their resemblance to worms, entice the smaller fishes, and they become the prey of their concealed enemy. It is surprising how varied the means are by which fishes obtain their food. The *chatodon* (bandouliere à bec) squirts water at flies as they pass and brings them down. The

* The spines of the Echinus, or Sea Urchin, are moveable ; they assist in progression. They are directed towards an advancing enemy ! Although these spines may be effectual for their purpose, they are the lowest or least perfect substitutes for the extremities.

sciæna jaculatrix, according to Pallas, has a similar power; and the *sparus insidiator* catches aquatic insects by the sudden projection of its snout. It is affirmed by some naturalists that the rays of the dorsal and anal fins, as in the cordonnier of Martinique (*zeus ciliaris*, le blepharis, Cuv.), are employed to grapple or coil round the stems of plants and sustain the fish.



The several offices attributed to these processes in fishes imply that they possess sensibility, if not muscular power.

By anatomical investigation and experiment, I, some years ago, discovered that the sensibility of all the head, and of its various appendages, resulted from one nerve only of the ten which are enumerated as arising from the brain, and

are distributed within and around the head; and, pursuing the subject by the aid of comparative anatomy, I found that a nerve corresponding to this, which is the fifth nerve in man, served a similar purpose in all the lower animals. In creatures which are covered with feathers or scales, or protected by shell, this nerve becomes almost the sole organ of sensibility. It is the development of this nerve which gives sensibility to the cirri, which hang about the mouths of fishes, and to the palpa of the crustacea and insects. It is the same nerve which supplies the tongue, and is the organ of its exquisite sensibility to touch, as well as of taste. In some animals, especially in the reptiles, the tongue, by its length and mobility, becomes a substitute for these external appendages. We might have noticed before, that the tongue is an organ of prehension as well as of touch. With it the ox gathers in the herbage; and in the giraffe, it is rather curious to observe that as the whole frame of the animal is calculated to raise the head to a great height, so is the tongue capable of projecting beyond the mouth to an extraordinary extent, to wrap round and pull down the extreme branches of trees. The whiskers of the feline quadrupeds possess a fine sensibility through branches of the fifth nerve, which enter their roots. Birds have a high degree of sensibility to touch in their mouths. In ducks, and

all that quaffer with their bills under water, the sense is very fine, and we find, on dissection, that a branch of the fifth nerve, remarkably developed, is distributed on the upper mandible. Animals feel in the whole of their external surface; and we may say that serpents, by coiling themselves round a body, have the organ of touch all over them. Still the fifth pair of nerves in the head, or the nerve analogous to it, is the main instrument of touch in the greater number of animals where extremities are wanting. There are organs varying in their conformation, sometimes delicate palpa, sometimes horny rods, and these are often possessed of muscularity as well as sensibility; but to all, the sense of touch is bestowed through a nerve corresponding with the fifth pair, the nerve of the tongue and lips, and of the muscles of the jaws in man.

But we may repeat, that, necessary as these appendages and this sensibility are to the existence of these animals, their imperfections serve, by contrast, to show how happily the different properties are combined in the hand; in which we perceive the sensibilities to changes of temperature, to touch, and to motion, united with a facility in the joints of unfolding and moving in every possible degree and direction, without abruptness or angularity, and in a manner inimitable by any artifice of joints and levers.

CHAPTER VI.

THE ARGUMENT PURSUED FROM THE COMPARATIVE ANATOMY. THE ANIMAL SYSTEM, AND THE REVOLUTIONS IN THE SOLID MATERIAL OF IT.

So far as we have hitherto proceeded, by examining objects in comparative anatomy which from their magnitude cannot be misunderstood, we have been led to conclude that, independently of the system of parts marvellously combined to form the individual animal, there is another more comprehensive system, which embraces all animals; and which exhibits a certain uniformity in the functions of life, however different in form or bulk the creatures may be, or to whatever condition of the globe they may have been adapted. We have seen no accidental deviation or deformity, but every change has been for a purpose, and every part has had its just relation. We have witnessed all the varieties moulded to such a perfect accommodation, and the alterations produced by such minute degrees, that all notion of external and accidental agency must be rejected.

We might carry our demonstration downward

through the lower classes of animals ; for example, we might trace the feet of insects from their most perfect or complex state, till they disappear ; or, observing the changes in another direction, we might follow out the same parts from the smallest beginning to the most perfect condition of the member, where we see the thigh, leg, and tarsus of the fly. We might distinguish them at first as the fine cirri, like minute bristles, which, on the bodies of worms take slight hold of the surface over which they creep. In the sea mouse, (*aphrodita*) we might notice these bristles standing out from distinct mammillary processes, which are furnished with appropriate muscles. Then in the *myriapodes*, the first order of insects, we might see the same "many feet," and each foot having a distinct articulation. From that, we might pass to the feet of those insects, where there is a thigh, leg, and foot, with the most perfect system of flexors, extensors, and adductor muscles, possessing, in fine, all that we most admire in the human anatomy. Nay, it is more curious to observe how the feet of the true insects are again changed or modified, taking new offices, the anterior feet becoming feelers, organs of prehension, or *hands*. When, with such an object, we view the delicate and curiously adapted instruments of insects, we must perceive that it would be easy to trace almost every part through a succession of modi-

fications. Among the *vertebrata*, we have seen the hand become a wing or a fin ; so might we trace the wings of insects. If we begin with a fly, which has two delicate and perfect wings incased and protected, we find that the covers are raised to admit the expansion of the wings. In another, the case becomes a wing ; and the fly is characterised by four wings. Proceeding to examine a third example, we shall discover that this anterior wing is larger and more perfect than the posterior : the fourth specimen has lost the posterior wings, and has only two perfect ones ; and if we continue the examination, the next specimen will present an insect deprived of wings altogether. These are not freaks of nature, but new forms of the body ; new appendages required for a different poising of the fly in its flight. They are adaptations in that regular series which we have observed to obtain in the larger animals, and where the intention can not be mistaken. A very natural question will force itself upon us, how are those varieties to be explained ?

The curious adaptation of a member to different offices and to different conditions of the animal has led to a very extraordinary opinion in the present day,—that all animals consist of the same elements. It would be just to say that they consist of the same chemical elements, and that they attract and assimilate matter by the

performance of the same vital functions, through every species of animals, however different in form and structure. But by the elements which are now mentioned, the authors of this new theory mean certain pieces which enter into the structure of the body; and which they suppose may be transposed and differently arranged. They illustrate their views by the analogy of the building materials of a house. If these materials, they say, are exhausted in the ornamental parts of the portico and vestibule, there must be a proportionate limitation of the apartments for the family.

This new theory has been brought forward with the highest pretensions; the authors of it have called upon us to mark the moment of its conception as the commencement of a new æra! They speak of the “ elective affinities of organs,” “ the balancing of organs,” “ a new principle of connection,” and a “ new theory of analysis.”—The hypothesis essentially is this, that when a part, which belongs to one animal, is missed in another, we are to seek for it in some neighbouring organ: and on such grounds they affirm, that this surpasses all former systems as a means of discovery. Now, the perfection or aggrandizement of any one organ of an animal is not attended with the curtailment or proportional deficiency of any other. Perhaps, the supporters of this theory dwell too much

upon the bones; but even in them, we shall show that the system is untenable. In the meantime, we may ask, do additional parts connected with the stomach, making it highly complex, as in ruminating animals, shorten the intestinal canal, or make its form simpler? On the contrary, is not a complex stomach necessarily connected with a long and complicated intestine? Does a complex intestinal canal throughout all its course, render the solid viscera which are in juxtaposition to it imperfect? Is there any defect in them, because the organs of digestion are perfect or complicated? Does the complex heart imply a more simple, or a more perfect condition of the lungs? In short, as animals rise in the scale of existence, do we not find that the systems of digestion, circulation, respiration, and sensation bear ever a proportional increase? Is there any instance of an improvement in one organ thrusting another out of its place, or diminishing its volume?

As to the osseous system, were we to follow these theorists into the very stronghold of their position, the bones of the skull, where the real intricacy of the parts allows them some scope for their ingenuity, we might show how untenable the principle is which they assume. But we must confine ourselves to our own subject.

In the higher orders of the vertebrata, we find that the bones of the shoulder perform a double

office; that they have an important share in the act of respiration, whilst they are perfect as a foundation for the extremity. Now, let us take an instance where the mode of respiration of the animal is inconsistent with what we may term the original mechanism of the bones of the shoulder. In the batrachian order, the ribs are wanting: where then are we to look for them? Shall we follow a system which informs us that when a bone is wanting in the cavity of the ear we are to seek for it in the jaw; yet, which, shall leave us in the contemplation of this class of animals deficient in thirty-two ribs, without pointing out where they are to be found, or how these elements are built up in other structures? If, on the contrary, we take the principle that parts are formed or withdrawn, with a never failing relation to the function which is to be performed, we see that no sooner are the compages of the chest removed, and the shoulder thus deprived of support, than the bones to which the extremity is fixed are expanded and varied, both in form and articulation, so as to fulfil their main object of giving security and a centre of motion to the arm.

With respect to the instance which we have accidentally noticed of the mechanism of the jaw in birds, and which is brought forward so vauntingly as a proof of the excellence of the theory, it does, indeed, prove the reverse of what

is assumed. The only effect of this hypothesis is to make us lose sight of the principle which ought to direct us in the observation of such curious structures, as well as of the conclusions to which an unbiassed mind would come. The matter to be explained is simply this:—the chain of bones in the ear, which is so curiously adapted in the mammalia to convey the vibrations of the membrane of the tympanum to the nerve of hearing, is not found in the organ of hearing in birds; but there is substituted a mechanism entirely different. They choose to say that the incus, one of the four bones of the chain, is wanting in the bird. Where shall we find it?—they ask. Here it is in the apparatus of the jaw or mandible; in that bone which is called *os quadratum*. I believe that the slight and accidental resemblance which this bone (B.) (see figure p. 159) in the bird has to the incus, is the real origin of this fancy. Let us follow a juster mode of reasoning, and see how this hypothesis obscures the beauty of the subject. The first step of the investigation ought to be to inquire into the fact, if there be any imperfection in the hearing of birds. That is easily answered—the hearing of birds is most acute; the slightest noise alarms; and the nightingale or other bird of song, in a summer evening, will answer to the note of his rival when he is out of our hearing. We have next to observe the imperfection in the

organ—the want of an external ear; which, were it present, would be at variance with all that we have most to admire in the shape of the bird and the direction of the feathers, as conducing to its rapid passage through the air. With this obvious defect of the external ear, can we admit that the internal ear is also imperfect, notwithstanding the very remarkable acuteness of hearing, which we know to result from this internal structure, and from it alone? Now we do, in fact, find a different structure in the ear of birds; but, yet nothing is wanting. The *columella* is a shaft of bone of exquisite delicacy, which is extended from the outward membrane of the ear to the labyrinth or proper seat of the nerve of hearing. It occupies the place and performs the office of the chain of four bones which belong to the ear of mammalia. We have no authority, however, for affirming that the incus is here wanting more than any other bone of the chain.

From this mode of inquiry, we find that the sense of hearing is enjoyed in an exquisite degree in birds: that the organ of the sense is not imperfect, but is adapted to a new construction, and a varied apparatus—suited to the condition of the bird: and that there is no accidental dislocation or substitution of something less perfect than what we find in other classes of animals.

If we now look to the structure of the mandible of the bird, we shall find as curious, though

a somewhat grosser example of mechanical relation. The bill of the bird, in some degree, pertains to our subject, as it is the organ of prehension and of touch. It is withal a fly trap—hence, its motions must be rapid: and the velocity is increased by the most obvious means imaginable,—that is, by giving motion to both mandibles, instead of to one. When a dog snaps, he throws back his head, and thereby raises the upper jaw at the same time that the lower jaw is dropped; but these are slow and clumsy motions, pertaining to the muscles of the neck as well as of the jaws, and the poor hound makes many attempts, before he catches the fly that teases him. But a swallow or fly-catcher makes no second effort, so admirably suited is the apparatus of prehension to the liveliness of the eye and the instinct. The adaptation of the instrument consists in this, that the muscles which open the



lower mandible, by the same effort, open the upper one: A. is a process of the lower mandible, projecting behind the centre of motion, and,

the muscle which is attached to it, opens the bill;—but at the same time, the lower mandible presses upon the bone B., the *os quadratum*: now, there is attached to this bone, projecting forwards, with its anterior extremity fixed against the upper mandible, a shaft or process of bone C.; and this receives the pressure of the *os quadratum*, when the muscle acts; so that being thrust forwards, like a bolt, it opens the upper mandible, which moves upon the skull at D.* Here, then, is a piece of mechanism as distinct as the lock of a gun, which is for the purpose, as we have said, of giving rapidity to the motions of the bill. Is it nearer the truth to consider this as a new apparatus, suiting the necessities of the creature, or an accidental result of the introduction of a bone, which in its proper office has nothing to do with the jaw?

But we have wandered somewhat from our subject. We have before taken the bones of the shoulder, or those of the extremity which are nearest to the trunk; we may pursue the inquiry by noticing those which are most remote from it. In the bones corresponding with those of the hand, we have seen that the same system was variously modified so as to be adapted to every possible change in office. But as it is insisted that the number of parts continue the same,

* There is another process of the *os quadratum*, which, directed more internally, assists in raising the upper mandible.

what can we say to the bones of the paddle in the saurian and chelonian tribes? These, as in the ichthyosaurus for example, consist of sixty or seventy polygonous bones; whilst in the horse there are only fifteen bones; and in man, twenty-seven. Yet, with all those bones in the paddle, there is still the full complement in the part that corresponds with the arm and fore arm. If the system fail us in such an obvious instance as this, with what confidence can we prosecute the intricate bones of the spine and head under its guidance? *

Seeking assistance from the works of distinguished naturalists, we do not always find that disposition of mind prevail, which we should be apt to suppose a necessary result of their peculiar studies. We do not discover that combination of genius with sound sense, which distinguished Cuvier, and the great men of science. It is, above all, surprising with what perverse ingenuity men seek to obscure the conception of a Divine Author, an intelligent, designing, and benevolent Being—rather clinging to the greatest absurdities, or interposing the cold and inanimate influence of the mere “elements,” in a manner to extinguish all feeling of dependance in our minds, and all emotions of gratitude.

* See Additional Illustrations, *On the position of the Head, &c.*

Some will maintain that all the varieties which we see, are the result of a change of circumstances influencing the original animal ; or that new organs have been produced by a desire and consequent effort of the animal to stretch and mould itself—that, as the leaves of a plant expand to light, or turn to the sun, or as the roots shoot to the appropriate soil, so do the exterior organs of animals grow and adapt themselves. We shall presently find that an opinion has prevailed that the organization of animals has determined their propensities ; but the philosophers, of whom we are now speaking, imagine the contrary,—that under the influence of new circumstances, organs have accommodated themselves, and assumed their particular forms.

It must be here remarked that there are no instances of the production of new organs by the union of individuals belonging to different species. Nor is there any foundation in observation for the opinion that a new species may be formed by the union of individuals of different families. But it is contended, that, although the species of animals have not changed in the last 5000 years, we do not know what might have been the effect of the revolution before that time ; that is, previous to the present condition of the world. On subjects of this nature, however, we must argue from what we know, and from what we see.

We do perceive surprising changes in the conformation of animals. Some of them are very familiar to us; but all show a foreknowledge and a prospective plan,—an alteration gradually taking place in preparation for the condition, never consequent upon it. It will be sufficient for our purpose, if we take the highest and the lowest examples. Man has two conditions of existence in the body. Hardly two creatures can be less alike than an infant and a man. The whole foetal state is a preparation for birth. My readers would not thank me, were I to show how necessary all the proportions and forms of the infant are to his being born alive,—and yet nothing is so easy to demonstrate. Every one may see that from the moment of birth there is a new impulse given to the growth, so as finally to adapt the proportions of the body to the state of perfect manhood. Few, however, are aware that the foetus has a *life* adapted to its condition, and that if the confinement of the womb were protracted beyond the appointed time, it must die!—from no defect of nourishment, but simply, because the time is come for a change in its whole economy!

Now, during all the long period of gestation, the organs are forming; the lungs are perfected before the admission of air—new tubes are constructed before the flood-gates, which are to

admit the blood, are opened. But there are finer, and more curious, provisions than these. If we take any of the grand organs, as the heart, or the brain, and examine it through all its gradations of change in the embryo state, we shall recognise it simple, at first, and gradually developing, and assuming the peculiarities which finally distinguish it. So that it is affirmed, and not without the support of a most curious series of observations, that the human brain, in its earlier stage, resembles that of a fish: as it is developed, it resembles more the cerebral mass of the reptile; in its increase, it is like that of a bird, and slowly, and only after birth, does it assume the proper form and consistence of the human encephalon. But in all these changes to which man is subject, we nowhere see the influence of the elements, or any other cause than that it has been so predestined. And if, passing over the thousand instances which might be gathered from the intermediate parts of the chain of animal existence, we take the lowest link, and look to the metamorphosis of insects, the conclusion will be the same.

For example, if we examine the larva of a winged insect, we shall see the provisions for its motion over the ground, in that condition, all admirably supplied in the arrangement of its muscles, and the distribution of its nervous system. But if, anticipating its metamorphosis,

we dissect the same larva immediately before the change, we shall find a new apparatus in progress towards perfection; the muscles of its many feet are seen decaying; the nerves to each muscle are wasting; a new arrangement of muscles, with new points of attachment, directed to the wings instead of the feet, is now visible; and a new distribution of nerves is distinctly to be traced, accommodated to the parts which are now to be put in motion. Here is no budding and stretching forth under the influence of the surrounding elements; but a change operated on all the economy, and prospective, that is, in reference to a condition which the creature has not yet attained.

These facts countenance the conclusion drawn from the comparative anatomy of the hand and arm—that with each new instrument, visible externally, there are a thousand internal relations established: a mechanical contrivance in the bones and joints, which alters every part of the skeleton: an arrangement of muscles, in just correspondence: a new and appropriate texture of nervous filaments, which is laid intermediate between the instrument and the very centre of life and motion; and, finally, we shall discover as we proceed, that new sources of activity must be created in relation to the new organ, otherwise the part will hang a useless appendage.

It must now be apparent that nothing less than the Power, which originally created, is equal to the effecting of those changes on animals, which are to adapt them to their conditions : that their organization is predetermined, and not consequent on the condition of the earth or the surrounding elements. Neither can a property in the animal itself, account for the changes which take place in the individual, any more than for the varieties which take place in the species. Every thing declares the species to have its origin in a distinct creation, not in a gradual variation from some original type ; and any other hypothesis than that of a new creation of animals suited to the successive changes in the inorganic matter of the globe—the condition of the water, atmosphere, and temperature—brings with it only an accumulation of difficulties.

We ought here to bring into the argument a series of changes of structure, of a different nature altogether : we mean the revolution that is taking place, without a pause during the whole life, in the frame of every individual animal. No description of the mechanical parts of the living body, or even of the forms, the instruments, or the organs of sense which have relation to external objects, can convey an idea of the power that is continually in operation,

unless we contemplate the influence of *life* itself, in collecting, arranging, and incessantly changing the material of the frame. Astounded by the magnitude of natural objects, bewildered by seeing neither beginning nor end, permitted only to witness those instances of decay which would almost persuade us that all objects in nature were given up to a power of destruction, it must be useful to have the proofs in the microcosm of the living body, that a system may be continued, whilst every portion of the substance suffers change.

Life draws the materials of the body apart from the influence of those affinities which hold the inorganic world together, and substitutes other laws. The wonders of the microscope are not greater than should be excited by looking to the early rudiments of some animal, it may be the largest that inhabits the earth. In a small portion of matter that seems homogeneous, transparent, soft, and like a jelly, there is only a pulsating point visible. What might be seen by employing the newly discovered properties of light, it is impossible to say; as polarized light exhibits in mineral bodies a structure not visible before, so we could imagine that some power bestowed upon our eye might discover a distinction of parts in what seems a drop of jelly. But the greater wonder is in proof before us, that this mass has a principle

of life—that it is not only ordered what this influence will perform, in attracting matter, and building up the complex structure of an animal body, but that the period of existence of that body is from its beginning defined. This life may be limited to a day, and truly ephemeral, or be protracted to a hundred years: and the period is adjusted, as perfectly as the mechanism and structure itself, to the condition of existence, the enjoyment of the individual, and the continuance of the species.

Nothing is more remarkable than the slight hold by which this life is possessed by some of these organic structures, and the tenacity of life in others. Slight changes of temperature or moisture will annihilate some, whilst others will be dried up into dust, or ribbed in ice, and after years admit of resuscitation.

If instead of contemplating the variety of animals as they are adapted to their place, we think of ourselves—there is no living creature in which it is so distinctly designed that the stages of life shall be marked—so that we may have continually before us the tenure by which we hold that life. But to our argument;—during all the progressive changes of life, the material is ever new; the poet's picture of the last stage of man's life is not a true one. If man totters under the burthen of years, the simile of a ruin is inapplicable; the material of his frame

is not different, and not older than that of a child—it is ever decaying, ever renewing whilst the office of digestion and assimilation goes on at all. The difference of activity in this change of the material of the body, compared with that of the child, may be as a week to a day; but here is not the cause of the gray hair, faded cheek, and feeble step. This is the stamp which the Creator has intended to be deciphered and interpreted.

Who, contemplating the many beautiful fabrics built up within an animal body, and seeing the proofs that they are not permanent, but, on the contrary, ever changing and ever forming anew—moreover, learning that these textures are formed by an energy, or life, which continues uniform in its operation, whilst all the materials that it works upon are changing—can hesitate to believe that in the changes of the inorganic matter around us there is a presiding Power. The difficulty of comprehension here must be attributed to the partial view which we have of these changes, from their extending into periods so far beyond our measure of time: but we cannot, at least, doubt that such a power may be in operation, and we must acknowledge that a balance is preserved, and that order and harmony prevail.

CHAPTER VII.

OF SENSIBILITY AND TOUCH.

WE find every organ of sense, with the exception of that of touch, more perfect in brutes than in man. In the eagle and the hawk, in the gazelle and in the feline tribe, the perfection of the eye is admirable;—in the dog, wolf, hyæna, as well as in birds of prey, the sense of smelling is inconceivably acute; and if we should have some hesitation in assigning a more exquisite sense of taste to brutes, we cannot doubt the superiority of that of hearing in the inferior animals. But in the sense of touch, seated in the hand, man claims the superiority; and it is of consequence to our conclusion that we should observe why it is so.

It has been said that, accompanying the exercise of touch, there is a desire of obtaining knowledge; in other words, a determination of the will towards the organ of the sense. Bichat says, it is active whilst the other senses are passive. This opinion implies that there is something to be understood—something deeper than what is here expressed. We shall arrive at the truth by considering that in the use of the

hand there is a double sense exercised; we must not only feel the contact of the object, but we must be sensible to the muscular effort which is made to reach it, or to grasp it in the fingers. It is in the exercise of this latter power that there is really an effort made; there is no more direction of the will towards the nerve of touch, than towards any other sensible nerve. But, before entering on the consideration of the sensibility and action which belong to the fingers, we must attend to the common sensibility of the surface.

Besides that the common sensibility belongs to the hand, and that some inquiry into it is necessary to the completion of our subject, I pursue it the more willingly, because there is no other which affords more surprising proofs of design and of benevolence in the Author of our being. However obvious the proofs may be which are drawn from the mechanism of the body, they are not to be compared, in that respect, to those which are derived from the living endowments of the frame.

I have used the term common sensibility in conformity with the language of authors and with customary parlance; but the expressions, the "common nerves," and the "common sensibility," in a philosophical inquiry, are inadmissible. Indeed, these terms have been the cause of much of the obscurity which has hung over

the subject of the nervous system, and of our blindness to the benevolent adaptation of the endowments of that system to the condition of animal existence. Thus, it has been supposed that some nerves are more coarsely provided for sensation, and that others are of a finer quality, adapted to more delicate impressions. It is assumed that the nerve of the eye is finer than the nerve of the finger—without considering that the retina is insensible to that quality of matter of which we readily acquire the knowledge through touch. Nerves are, indeed, appropriated to peculiar senses, and to the bestowing of distinct functions, but delicacy of texture has nothing to do with this. The nerve of touch in the skin is insensible to light or to sound, not because it has a coarser or more common texture: the beauty and perfection of the system is, that each nerve is made susceptible to its peculiar impression only. The nerve of the skin is alone capable of giving the sense of contact, as the nerve of vision is confined to its own office. If this appropriation resulted merely from a more delicate texture: if the retina were sensible to the matter of light only from possessing a finer sensibility than the nerve of touch, it would be a source of torment; whereas it is most beneficently provided that it shall not be sensible to pain, nor be capable of conveying any impressions to the mind, but those which

operate according to its proper function, producing light and colour.

The pain which we experience in the eye, and the irritation from dust, are owing to a distinct nerve from that of vision, and are consequent on the susceptibility of the surface to a different kind of impression; of which more presently. We should keep in mind the interesting fact, that when surgeons perform the operation of couching, the point of the needle, in passing through the outer coat of the eye, gives a sensation of pricking, which is an exercise of the nerve of touch; but when the point passes through the retina, which is the expanded nerve of vision, and forms the internal coat of the eye, the sensation that is produced is as of a spark of fire. The nerve of vision is as insensible to touch as the nerve of touch is to light.*

The extreme sensibility of the skin to the slightest injury conveys to every one the notion—that the pain must be the more severe the deeper the wound. This is not the fact, nor would it accord with the beneficent design

* The views of the nervous system, which are shortly given in the text, guided me in my original experiments made twenty-two years ago. They have been attributed to foreign physiologists. The ignorance of what has been done in England, may be, for strangers, an excuse for maintaining these opinions as their own; but the authors at home, who should have known what has been taught in this country, are inexcusable when they countenance these assumptions.

which shines out every where. The sensibility of the skin serves not only to give the sense of touch, but it is a guard upon the deeper parts; and as they cannot be reached except through the skin, and we must suffer pain, therefore, before they are injured, it would be superfluous to bestow sensibility upon these deeper parts. If the internal parts which act in the motions of the body had possessed a similar degree and kind of sensibility with the skin, so far from serving any useful purpose, this sensibility would have been a source of inconvenience and continual pain in the common exercise of the frame.

Surgeons have better opportunities of advancing physiology than physicians, as they become practically acquainted with the phenomena on which the science is founded. The surgeon who has to perform an operation by incision, when he has cut through the skin, informs his patient that the greatest pain is over. If, in the advanced stage of the operation, he has to extend the incision of the skin, it is very properly considered as a great awkwardness; and this not only because it proves that he has miscalculated what was necessary to the correct performance of his operation, but because the patient, bearing courageously the deeper incisions, cannot sustain the renewed cutting of the skin, without giving token of severe pain.

The fact of the exquisite sensibility of the surface, in comparison with the deeper parts, being thus ascertained by daily experience, we cannot mistake the intention : that the skin is made a safeguard to the delicate textures which are contained within, by forcing us to avoid injuries : and it does afford us a more effectual defence than if our bodies were covered with the hide of the rhinoceros.

The fuller the consideration which we give to this subject, the more convincing are the proofs that the painful sensibility of the skin is a benevolent provision, making us alive to those injuries, which, but for this quality of the nervous system, would bruise and destroy the internal and vital parts. In pursuing the inquiry, we learn with much interest that when the bones, joints, and all the membranes and ligaments which cover them, are exposed—they may be cut, pricked, or even burned, without the patient or the animal, suffering the slightest pain. These facts must appear to be conclusive ; for who, witnessing these instances of insensibility, would not conclude that the parts were devoid of sensation. But when we take the true, philosophical, and I may say the religious view of the subject, and consider that pain is not an evil, but given for benevolent purposes and for some important object, we should be unwilling to terminate the investigation here.

In the first place, we must perceive that if a sensibility similar to that of the skin had been given to these internal parts, it must have remained unexercised. Had they been made sensible to pricking and burning, they would have possessed a quality which would never have been useful, since no such injuries can reach them ; or never without warning being received through the sensibility of the skin.

But, further, if we find that sensibility to pain is a benevolent provision, and is bestowed for the purpose of warning us to avoid such violence as would affect the functions or uses of the parts, we may yet inquire whether any injury can reach these internal parts without the sensibility of the skin being excited. Now, of this there can be no doubt, for they are subject to sprain and rupture, and shocks, without the skin being implicated in the accident. If we have been correct in our inference, there should be a provision to guide us in the safe exercise of the limbs : and notwithstanding what has been apparently demonstrated of the insensibility of these internal parts, they must possess an appropriate sensibility, or it would imply an imperfection.

With these reflections, we recur to experiment—and we find that the parts which are insensible to pricking, cutting, and burning,

are actually sensible to concussion, to stretching, or laceration.

How consistent, then, and beautiful is the distribution of this quality of life! The sensibility to pain varies with the function of the part. The skin is endowed with sensibility to every possible injurious impression which may be made upon it. But had this kind and degree of sensibility been made universal, we should have been racked with pain in the common motions of the body: the mere weight of one part on another, or the motion of the joint, would have been attended with that degree of suffering which we experience in using or walking upon an inflamed limb.

But on the other hand, had the deeper parts possessed no sensibility, we should have had no guide in our exertions. They have a sensibility, limited to the kind of injury which it is possible may reach them, and which teaches us what we can do with impunity. If we leap from too great a height, or carry too great a burthen, or attempt to interrupt a body whose impetus is too great for us, we are warned of the danger as effectually by this internal sensibility, as we are of the approach of a sharp point or a hot iron to the skin.

Returning to the consideration of the sensibility of the skin, in order more fully to com-

prehend the benevolent effect of it, or in other words, its necessity to our very existence, I may be excused for stating the argument to the reader as I have delivered it in my lectures to the College of Surgeons.

“ Without meaning to impute to you inattention or restlessness, I may request you to observe how every one occasionally changes his position and shifts the pressure of the weight of his body ; were you constrained to retain one position during the whole hour, you would rise stiff and lame. The sensibility of the skin is here guiding you to that, which if neglected, would be followed even by the death of the part. When a patient has been received into the hospital with paralysis of the lower part of the body, we must give especial directions to the nurse and attendants that the position of his limbs be changed at short intervals, that pillows be placed under his loins and hams, and that they be often shifted. If this be neglected, you know the consequence to be inflammation of the parts that press upon the bed ; from which come local irritation, then fever and mortification and death.

“ Thus you perceive that the natural sensibility of the skin, without disturbing your train of thought, induces you to shift the body so as to permit the free circulation of the

“ blood in the minute vessels: and that when
“ this sensibility is wanting, the utmost atten-
“ tion of friends and the watchfulness of the
“ nurse are but a poor substitute for this pro-
“ tection which nature is continually affording.
“ If you suffer thus lying on a soft bed, when
“ deprived of the sensibility of the skin, how
“ could you encounter without it the rubs and
“ impulses incident to an active life? You must
“ now acknowledge that the sensibility of the
“ skin is as much a protection to the frame
“ generally, as the sensibility of the eyelids is to
“ the eyes, and gives you a motive for gratitude
“ which probably you never thought of.”

The sensibility of the hand to heat, is a different endowment from that of touch. This sensibility to the varieties of temperature is seated in the skin, and is, consequently, limited to the exterior surface of the body. The internal parts of the body being of a uniform temperature, it would have been, in them, a quality altogether superfluous. But as we are surrounded by a temperature continually varying, and are subject to destruction by its extremes, and as we must suit our exertions or our contrivances so as to sustain life against these vicissitudes, our possession of this peculiar sensibility on the surface affords another proof of there having been a foreknowledge of our condition. We might, indeed, take our former example in evidence of

what must befall through the want of this sensibility—the paralytic is brought to us severely burned, or with his extremities mortified through cold. A man having lost the sense of heat in his right hand, but retaining the muscular power, lifted the cover of a pan which had fallen into the fire and deliberately replaced it, not being conscious that it was burning hot; the effect, however, was the death and destruction of the skin of the palm and fingers. In this man there was a continual sensation of coldness in the affected arm, which actual cold applied to the extremity did not aggravate, nor heat in any degree assuage.* Sensibility to heat is a safeguard in as much as it is capable of becoming a painful sensation, whilst it is a never-failing excitement to activity and a continual source of enjoyment.

And here we may remark an adaptation of the living property very different from the physical influence. Heat is uniform in its effect on matter; but the sensation varies as it is given to or abstracted from the living body. Cold and heat are distinct sensations; and this is so far important that without such contrast we should not continue to enjoy the sense. For in the nervous system it holds universally that

* There are certain morbid conditions of sensation when cold bodies feel intensely hot.—*Dr. Abercrombie's Inquiry into the Intellectual powers.*

variety or contrast is necessary to sensation, the finest organ of sense losing its property by the continuance of the same impression. It is by a comparison of cold and heat that we enjoy either condition.

To contrast still more strongly the sensibility of the surface with the property of internal parts, to show how very different sensibility is, in reality, from what is suggested by first experience, and how admirably it is varied and accommodated to the functions, we shall add one other fact. The brain is insensible—that part of the brain, which if disturbed or diseased, takes away consciousness, is as insensible as the leather of our shoe! That the brain may be touched, or a portion of it cut off, without interrupting the patient in the sentence that he is uttering, is a surprising circumstance! From this fact Physiologists formerly inferred that the surgeon had not reached the more important organ of the brain. But that opinion arose from the notion prevailing that a nerve must necessarily be sensible. Whereas, when we consider that the different parts of the nervous system have totally distinct endowments, and that there are nerves, as I have elsewhere shown, insensible to touch and incapable of giving pain, though exquisitely alive to their proper office, we have no just reason to conclude that the brain should be sensible, or exhibit the property

of a nerve of the skin. Reason on it as we may, the fact is so;—the brain, through which every impression must be conveyed before it is perceived, is itself insensible. This informs us that sensibility is not a necessary attendant on the delicate texture of a living part, but that it must have an appropriate organ, and that it is an especial provision.*

To satisfy my reader on this interesting subject, I shall take the contrast of two organs, one external and exposed, and the other internal and carefully excluded from injury.

The eye, consisting of its proper nerve of vision and its transparent humours and coats, is an organ of exquisite delicacy—not only is it exposed to all the injuries to which the general surface of the body is liable, but to be inflamed and rendered opaque by particles getting into it which are so light that they float in the atmosphere, and to the contact of which the common skin is quite insensible. The mechanical, and more obvious contrivance for the protection of this organ, is a ready motion of the eyelids and the shedding of tears; which coming, as it were, from a little fountain, play over the surface of the eye, and wash away whatever is offensive. But to the action of this little hydraulic and mechanical apparatus there is required an ex-

* See the Sensibility of the Retina, “Additional Illustrations.”

quisite sensibility to direct it—not that kind of sensibility which enables the eye to receive the impressions of light—but a property more resembling the tenderness of the skin, yet happily adapted, by its fineness, to the condition of the organ.

A nerve, possessed of a quality totally different from that of the optic nerve, extends over all the exterior surfaces of the eye, and gives to those surfaces their delicate sensibility. Now it sometimes happens that this nerve is injured and its function lost; the consequences of which are very curious,—smoke and offensive particles, which are afloat in the atmosphere, rest upon the eye: flies and dust lodge under the eyelids, without producing sensation, and without exciting either the hydraulic or the mechanical apparatus to act for the purpose of expelling them. But although they do not give pain, they nevertheless stimulate the surfaces so as to produce inflammation, and that causes opacity in the fine transparent membranes of the eye; and the organ is lost, although the proper nerve of vision remains entire. I have seen many instances of the eye being thus destroyed for want of sensibility to touch,* and it has been curious to remark, on these occasions, that when

* They are stated at length in my papers in the Philosophical Transactions, and in the Appendix of my work on the Nervous System.

the hand was waved or a feather brought near the eye, the person winked ; yet he did not shut his eye on rubbing the finger across the eyeball, or when blood was removed by the lancet from the inflamed vessels. In those cases, when vision gave notice of danger to the organ, the patient winked to avoid it, but when the point touched the eye or eyelids, the sense of touch gave no alarm, and was followed by no action for the protection of the organ.

I shall present another instance of the peculiar nature of the sensibility which protects the eye. The Oculist has observed that by the touch of a thing as light as a feather, the muscles of the eye will be thrown into uncontrollable actions and spasms : but if the point of the finger be pressed somewhat rudely between the eyelids, and directly on the eye itself, he can by such means hold the eye steady for his intended operation, producing hardly any sensation, certainly no pain !

This is one of the little secrets of the art ; the Oculist turns out the eyelids, and fingers the eye, in a manner which appears, at once, rude and masterly : and still the wonder grows that he can do such things with so much dexterity as to inflict no pain, when by daily experience we know that even a grain of sand in the eye will torture us. The explanation is this : the eye and eyelids are possessed of a sensibility

which is adjusted to excite the action of its protecting parts against such small particles as might lodge and inflame its fine membranes. But the apparatus is not capable of protecting the surface of the eye against the intrusion of a stick or a stone; from such injuries it could not be defended by a delicate sensibility and involuntary action, but only by the effort of the will.

In these details we have new proofs of the minute relation which is established between the species of sensibility in an organ and the end to be attained through it. It will not be denied that if it were not for the pain to which the eye is exposed, we should quickly lose the enjoyment of the sense of vision altogether. But we were about to institute a comparison of the eye with the heart.

The observation of the admirable Harvey, the discoverer of the circulation of the blood, is to this effect. A noble youth of the family of Montgomery, from a fall and consequent abscess on the side of the chest, had the interior marvellously exposed, so that after his cure, on his return from his travels, the heart and lungs were still visible and could be handled; which when it was communicated to Charles I., he expressed a desire that Harvey should be permitted to see the youth and examine his heart. "When," says Harvey, "I had paid my re-

“ spect to this young nobleman, and conveyed
“ to him the king’s request, he made no con-
“ cealment, but exposed the left side of his
“ breast, when I saw a cavity into which I could
“ introduce my fingers and thumb; astonished
“ with the novelty, again and again I explored
“ the wound, and first marvelling at the extra-
“ ordinary nature of the cure, I set about the
“ examination of the heart. Taking it in one
“ hand, and placing the finger of the other on
“ the pulse of the wrist, I satisfied myself that it
“ was indeed the heart which I grasped. I then
“ brought him to the king, that he might behold
“ and touch so extraordinary a thing, and that
“ he might perceive, as I did, that unless when
“ we touched the outer skin, or when he saw our
“ fingers in the cavity, this young nobleman
“ knew not that we touched the heart!” Other
observations confirm this great authority, and
the heart is declared insensible. And yet the
opinions of mankind must not be lightly con-
demned. Not only does every emotion of the
mind affect the heart, but every change in the
condition of the body is attended with a corres-
ponding change in the heart: motion during
health—the influence of disease—every passing
thought will influence it. Here is the distinction
manifested. The sensibility of the surface of
the eye is for a purpose, and so is the sensibility
of the heart. Whilst that of the eye guards it

against injury from without, the heart, insensible to touch, is yet alive to every variation in the circulation, subject to change from every alteration of posture or of exertion, and is in sympathy of the strictest kind with the constitutional powers.

When we consider these facts, we can no longer doubt that the sensibilities of the living frame are appropriate endowments; not qualities necessarily arising from life; still less the consequences of delicacy of texture. Nor can we, I should hope, longer doubt that they are suited to the condition, and especially to the degree of exposure of each part, and for its protection. We perceive that the sensibilities vary in an extraordinary manner as they are given to external or to internal parts, as they belong to one apparatus of action or to another, and they are ever adapted to excite some salutary or necessary action. We perceive no instance of pain being bestowed as a source of suffering or punishment purely, or without finding it overbalanced by great and essential advantages—without, in short, being forced to admit that no happier contrivance could be found for the protection of the part. It is provided that the more an organ is exposed, and in proportion to its delicacy of organization—the more exquisitely contrived is the apparatus for its protection, and the more peremptory the call for the

activity of that mechanism. The motive to action admits of no thought and no hesitation, and the action is more instantaneous than the quickest suggestion or impulse of the will.

We are speaking of the natural functions of the body. It requires a deeper consideration, and is indeed foreign to my subject to speak of the pains which result from disease, or to reconcile those who suffer in an extraordinary degree to the dispensations of Providence. But as a witness I may speak. It is my daily duty to visit certain wards of the hospital, where there is no patient admitted but with that complaint which most fills the imagination with the idea of insufferable pain and certain death. Yet these wards are not the least remarkable for the composure and cheerfulness of their inmates. The individual who suffers has a mysterious counterbalance to that condition, which to us who look upon her, appears to be attended with no alleviating circumstance.

It affords an instance of the boldness with which philosophers have questioned the ways of Providence, that they have asked—why were not all our actions performed at the suggestion of pleasure? why should we be subject to pain at all? In answer to this I should say, in the first place, that consistently with our condition, our sensations and pleasures, there must be

variety in the impressions; such contrast and variety are common to every organ of sense; and the continuance of an impression on any one organ, occasions it to fade. If the eye continue to look steadfastly upon one object, the image is soon lost—if we continue to look on one colour, we become insensible to that colour, and opposite colours to each other are necessary for a perfect impression.* So have we seen that in the sensibilities of the skin variations are necessary to continued sensation.

It is difficult to say what these philosophers would define as pleasure: but whatever exercise of the senses it should be, unless we are to suppose an entire change of our nature, its opposite is also implied. Nay, further, in this fanciful condition of existence, did anything of our present nature prevail, emotions purely of pleasure would lead to indolence, relaxation, and indifference. To what end should there be an apparatus to protect the eye, since pleasure could never move us to its exercise? Could the wind-pipe and the interior of the lungs be protected by a pleasurable sensation attended with the slow determination of the will—instead of the rapid and powerful influence which the exquisite sensibility of the throat has upon the

* See Additional Illustrations.

act of respiration, or those forcible yet regulated exertions, which nothing but the instinctive apprehension of death could excite?

To suppose that we could be moved by the solicitations of pleasure and have no experience of pain, would be to place us where injuries would meet us at every step and in every motion, and whether felt or not, would be destructive to life. To suppose that we are to move and act without experience of resistance and of pain, is to suppose not only that man's nature is changed, but the whole of exterior nature also—there must be nothing to bruise the body or hurt the eye, nothing noxious to be drawn in with the breath: in short, it is to imagine altogether another state of existence, and the philosopher would be mortified were we to put this interpretation on his meaning. Pain is the necessary contrast to pleasure: it ushers us into existence or consciousness: it alone is capable of exciting the organs into activity: it is the companion and the guardian of human life.

CHAPTER VIII.

OF THE SENSES GENERALLY, INTRODUCTORY TO
THE SENSE OF TOUCH.

ALTHOUGH we are most familiar with the sensibility of the skin, and believe that we perfectly understand the nature of the impressions upon it and the mode of their conveyance to the sensorium, yet there is a difficulty in comprehending the operations of all the organs of the senses—a difficulty not removed by the apparent simplicity of that of touch.

There was a time when the enquirer was satisfied by finding that in the ear there was a little drum and a bone to play upon it, with an accompanying nerve. This was deemed a sufficient explanation of the organ of hearing. It was thought equally satisfactory if, in experimenting upon the eye, the image of the object were seen painted at the bottom on the surface of the nerve. But although the impression be thus traced to the extremity of the nerve, still we comprehend nothing of the nature of that impression, or of the manner in which it is trans-

mitted to the sensorium. To the most minute examination, the nerves, in all their course, and where they are expanded into the external organs of sense, seem the same in substance and in structure. The disturbance of the extremity of the nerve, the vibrations upon it, or the images painted upon its surface, cannot be transmitted to the brain according to any physical laws that we are acquainted with. The impression on the nerve can have no resemblance to the ideas suggested in the mind. All that we can say is, that the agitations of the nerves of the outward senses are the signals, which the Author of nature has made the means of correspondence with the realities. There is no more resemblance between the impressions on the senses and the ideas excited by them, than there is between the sound and the conception raised in the mind of that man who, looking out on a dark and stormy sea, hears the report of cannon, which conveys to him the idea of despair and shipwreck—or between the impression of light on the eye, and the idea of him, who, having been long in terror of national convulsion, sees afar off a column of flame, which is the signal of actual revolt.

By such illustrations, however, we rather show the mind's independence of the organ of sense, and how a tumult of ideas will be excited by an impression on the retina, which, notwith-

standing, may be no more intense than that produced by a burning taper. They are instances of excited imagination. But even the determined relations which are established, in a common act of perception, between the sensation and the idea in the mind, have no more actual resemblance. How the consent, which is so precise and constant, is established, can neither be explained by anatomy nor by physiology nor by any mode of physical inquiry whatever.

From this law of our nature, that certain ideas originate in the mind in consequence of the operation of corresponding nerves, it follows—that one organ of sense can never become the substitute for another, so as to excite in the mind the same idea.

When an individual is deprived of the organs of sight, no power of attention, or continued effort of the will, or exercise of the other senses, can make him enjoy the class of sensations which is lost. The sense of touch may be increased in an exquisite degree; but were it true, as has been asserted, that individuals can discover colours by the touch, it could only be by feeling a change upon the surface of the stuff and not by any perception of the colour. It has been my painful duty to attend on persons who have pretended blindness, and that they could see with their fingers. But I have ever found

that by a deviation from the truth in the first instance, they have been entangled in a tissue of deceit; and have at last been forced into admissions which demonstrated their folly and weak inventions. I have had pity for such patients when they have been the subjects of nervous disorders which have produced extraordinary sensibility in their organs—such as a power of hearing much beyond our common experience. This acuteness of sensibility having attracted high interest and admiration, has gradually led them to pretend to powers greater than they actually possessed. In such cases it is difficult to distinguish the symptoms of disease, from the pretended gifts which are boasted of.

Experiment proves, what is suggested by Anatomy, that not only the organs of the senses are appropriated to particular classes of sensations, but that the nerves, intermediate between the brain and the outward organs, are respectively capable of receiving no other sensations but such as are adapted to their particular organs. Every impression on the nerve of the eye, or of the ear, or on the nerve of smelling, or of taste, excites only perceptions of vision, of hearing, of smelling, or of tasting; not solely because the extremities of these nerves, individually, are suited to external impressions, but because the nerves, through their whole course and wherever they are irritated, are capable of exciting

in the mind the idea to which they are appropriate, and no other. A blow, an impulse quite unlike that for which the organs of the senses are provided, will excite them all in their several ways; the eyes will flash fire, while there is noise in the ears. An officer received a musket-ball which went through the bones of his face—in describing his sensations, he said that he felt as if there had been a flash of lightning, accompanied with a sound like the shutting of the door of St. Paul's.

On this circumstance, that every nerve is appropriated to its function, depend the false sensations which accompany the morbid irritation of the nerves from internal causes, when there is in reality nothing presented externally;—such as flashes of light, ringing of the ears, and bitter taste or offensive smells. These sensations are caused, through the excitement of the respective nerves of sense, by derangement of some internal organ, and most frequently of the stomach.

But my chief object is to show that the most perfect proof of power and of design, is to be found in this, that the perceptions or ideas arising in the mind, are in correspondence with the qualities of external matter; and that, although the manner in which the object presented to the outward sense and the idea of it are connected, must ever be beyond our com-

prehension, they are, notwithstanding, indissolubly united; and when the object is so presented to us by the senses, it is attended with the conviction of its real existence—a conviction, independent of reason and to be regarded as a first law of our nature.

The doctrine of vibrations as applicable to vision, has had powerful advocates in our day. But it is quite at variance with anatomy, and assumes more than is usually granted to hypotheses. It requires that we shall imagine the existence of an ether; and that this fluid shall have laws unlike any other of which we have experience. It supposes a nervous fluid and tubes or fibres in the nerve, to receive and convey these vibrations. It supposes everywhere *motion* as the sole means of propagating sensation.

These opinions have been formed on the misconception that if a certain kind or degree of vibration be communicated to any nerve, this particular motion must be propagated to the sensorium, and a corresponding idea excited in the mind. For example, it is conceived that if the nerve of hearing were placed in the bottom of the eye, it would be impressed with the vibration proper to light, and that this being conveyed to the brain, the sensation of light or colours would result.—All which is contrary to fact.

Nor can I be satisfied with the statement that

light and colours result from vibrations which vary “from four hundred and fifty-eight millions of millions, to seven hundred and twenty-seven millions of millions in a second,” when I find that a fine needle pricking the retina will produce brilliant light, and that the pressure of the finger on the ball of the eye will give rise to all the colours of the rainbow!

There is a condition of the percipient or sentient principle, of the brain and nerves, as well as of the organ of sense, conforming to the impression to be made; a condition which corresponds with the qualities of matter. The organs of sense may be compared to so many instruments, which the philosopher applies to distinguish the several qualities of the body which he investigates. The different properties of that body are not communicable through any one instrument; and so in the use of the senses, each organ is provided for receiving a particular influence, and no other.

However mortifying it may be to acknowledge ignorance, variation of motion in a body cannot be admitted as the cause of sensation universally; nor, as I said, can we comprehend anything of the manner in which the nerves are affected; certainly we know nothing of the manner in which sensation is propagated or the mind ultimately influenced. But there is a very pleasing view of the subject, notwithstanding;—which is to

observe the correspondence of the mind (through a series of organic parts) with the external world, or with the condition and qualities of matter: than which nothing can convey a more sublime idea of Power, and of the system or unity of organic and inorganic creations.

Returning to the consideration of the sensibility of the skin and the sense of touch, this property is as distinct an endowment as that which belongs to the eye. It is neither inferior nor more common. It is not consequent upon the mere exposure of the delicate surface of the animal body. It is a distinct sense, the organ of which is seated in the skin; and it is necessary that this organ of sense should be extended widely over the surface of the body. Yet the nerves are as appropriate and distinct as if they were gathered into one trunk, such as we find them to be in the organs of vision and hearing.

Although the portion of nervous matter on which the sensation of touch depends be necessarily extended in its sentient extremities over the whole exterior surface of the body, it is very much concentrated towards the brain: and it is there appropriated, in the same manner as the nerves of vision and of hearing, to its peculiar function of raising corresponding perceptions in the mind.

Perhaps this will be better understood from the fact—that a certain large portion of the

skin may be the seat of excruciating pain, and yet the surface, which to the patient's perception is the seat of that pain, will be altogether insensible to cutting, burning, or any mode of destruction! "I have no feeling in all the side of my face, and it is dead; yet surely it cannot be dead, since there is a constant pricking pain in it." Such were the words of a young woman whose disease was at the root of the nerve of sensibility near the brain.* The disease destroyed the function of this nerve of the head, as to its property of conveying sensation from the exterior; and substituted that morbid impression on the trunk of the nerve, which was referred to the tactile extremities.

If we use the term common sensibility, we can do so only in reference to touch: as it is the sense that is most necessary to animal existence; and as it is enjoyed by all animals from the lowest to the highest in the chain of existence.

Whilst this sense is distinct from the others, it is the most important of all; since through it alone some animals possess the consciousness of existence; and to those which enjoy many organs of sense, that of touch, as we shall presently show, is necessary to the full development of the powers of all the other organs.

* See papers by the author in the Philosophical Transactions.

OF THE ORGAN OF TOUCH.

Touch is that peculiar sensibility which gives the consciousness of the resistance of external matter, and makes us acquainted with the hardness, smoothness, roughness, size, and form of bodies. It enables us to distinguish what is external from what belongs to us; and while it informs us of the geometrical qualities of bodies, we must refer to this sense also our judgment of distance, of motion, of number, and of time.

Presuming that the sense of touch is exercised by means of a complex apparatus—by a combination of the consciousness of the action of the muscles with the sensibility of the proper nerves of touch, we shall, in the first place, examine in what respect the organization resembles that of the other senses.

We have said before that, on the most minute examination of the extremity of a nerve, no appropriate structure can be detected; and that the nerves expanded on the organs of sense appear every where the same,—soft, pulpy, prepared for impression, and so distributed that the impression shall reach them. What is termed the structure of the organ of sense, is that apparatus by which the external impression is conveyed inwards, and by which its force is concentrated on the extremity of the nerve.

The mechanism by which those external organs are suited to their offices, is highly interesting ; it serves to shew (in a way that is level to our comprehension, as most resembling things of human contrivance) the design with which the fabric is constructed. Thus, the eye is so seated and so formed as to embrace the greatest possible field of vision ; we can understand the happy effects of the convexity of the transparent cornea, the influence of three humours of various densities acting like an achromatic telescope ; we can admire the precision with which the rays of light are concentrated on the retina, and the beautiful provision for enlarging or diminishing the pencil of light, in proportion to its intensity. But all this explains nothing, in respect to the perception that is excited in the mind by the impulse on the extremity of the nerve.

In like manner, in the complex apparatus of the ear, we see how this organ is formed with reference to a double course of impressions,—as they come through the solids or the body itself, and as they come through the atmosphere ; we comprehend how the undulations and vibrations of the air are collected and concentrated ; how they are directed, through the intricate passages of the bone, to a fluid in which the nerve of hearing is suspended ; and we see how, at last, that nerve is moved. But we can comprehend

nothing more from the study of the external organ of hearing.

The illustration is equally clear in reference to the organ of smelling, or of taste. There is nothing in the nerve itself, either of the nose or of the tongue, which can explain why it is susceptible of the particular impression. For these reasons, we are prepared to expect very little complexity in the organ of touch, and to believe that the peculiarity of the sense consists more in the property which has been bestowed on the nerve, than in the mechanical adaptation of the exterior organ.

OF THE CUTICLE.

The cuticle or epidermis covers the true skin, excludes the air, limits the perspiration, and in some degree regulates the heat of the body. It is a dead or insensible covering; it guards from contact the true vascular surface of the skin; and in this manner, it often prevents the communication of infection. We are most familiar with it as that scarf skin which scales off after fevers, or by the use of the flesh-brush, or by the friction of the clothes; for it is continually separating in thin scales, whilst it is as regularly formed anew by the vascular surface below. The condition of this covering is intimately connected with the organ of touch. The

habit of considering things as produced accidentally, has induced some anatomists to believe that the cuticle is formed by the hardening of the true skin. The fact, however, that the cuticle is perfect in the new-born infant, and that even then it is thickest on the hands and feet, should have shewn that, like every thing in the animal structure, it participates in the great design.

The cuticle is the organ of touch in this respect, that it is the medium through which the external impression is conveyed to the nerves of touch ; and the manner in which this is accomplished is not without interest. The extremities of the fingers exhibit all the provisions for the exercise of this sense. The nails give support to the fingers ; they are made broad and shield-like,* in order to sustain the elastic cushion which forms their extremity ; and the fulness and elasticity of the ends of the fingers adapt them admirably for touch.

The cushion on the end of the finger is a very important part of the exterior apparatus. An ingenious gentleman has observed that we cannot feel the pulse at the wrist with the tongue. It is a very remarkable fact, and I apprehend the reason to be, not the insensibility of the tongue, but the soft texture of it. It is not fitted to convey the peculiar impulse, to which the firm and

* *Unguis scutiformis.*

elastic pad of the finger is peculiarly suited. Is it not interesting to find that we should positively lose one of our inlets to knowledge of matter, were the organs of touch formed as delicately as the tongue!

But to return—on a nearer inspection, we see a more particular provision in the points of the fingers. Wherever the sense of feeling is most exquisite, there are minute spiral ridges of cuticle. These ridges have, corresponding with them, depressed lines on the inner surface of the cuticle; and these again give lodgment to a soft pulpy matter, in which lie the extremities of the sentient nerves. There the nerves are sufficiently protected, while they are exposed to impressions through the elastic cuticle, and thus give the sense of touch. The organization is simple, yet it is in strict analogy with the other organs of sense.

Every one must have observed a tendency in the cuticle to become thickened and stronger by pressure and friction. If the pressure be partial and severe, the action of the true skin is too much excited, fluid is thrown out, and the cuticle is raised in a blister. If it be still partial, but more gradually applied, a corn is formed. If, however, the general surface of the palms or soles be exposed to pressure, the cuticle thickens, until it becomes a defence like a glove or a shoe. Now, what is most to be

admired in this thickening of the cuticle is, that the sense of touch is not lost, or indeed diminished, certainly not at all in proportion to the protection afforded by the thickening of the skin.

The thickened cuticle partakes of the structure of the hoofs of animals: and we shall now attend to the nature of the hoof, as the best possible illustration of the manner in which the sensibility of the skin is in a due degree preserved whilst the surface is guarded.

The human nail is a continuation of the cuticle, and the hoof of an animal belongs to the same class of parts. In observing the manner in which the nerves enter the hoof, we have, in fact, a magnified view of the structure which exists, being only more minute and delicate, in the cuticular covering of the fingers. We may take the horse's foot as the example. When the crust or hoof, which is insensible, is separated from the part which, during life, possessed vascularity and sensibility, we see small villi* hanging from the vascular surface, and which have been withdrawn from the crust; looking to the inside of the crust, we perceive the pores from which these villi have been pulled. These processes from the vascular surface are not merely extremities

* VILLI, delicate tufts, like the pile of velvet, projecting from the surface of any membrane.

of nerves ; they consist of the nerves with the necessary accompaniment of membrane and blood vessels, on a very minute scale. For it must be remembered that nerves can perform no function unless supplied with blood, all qualities of life being supported through the circulating blood. These nerves, so prolonged within the villi into the hoof, receive the vibrations of that body. By this means the horse is sensible to the motion and pressure of its foot, or to its percussion against the ground ; and without this provision, there would be a certain imperfection in the limb.

In a former part of this treatise I have shewn by what curious mechanism the horse's foot is made yielding and elastic, for the purpose of enabling it to bear the percussion against the ground. But in made roads, and with the imperfections of shoeing, the pressure and concussion are too severe and too incessant ; so that the protecting sensibility of the foot is converted into a source of pain from the inflammation which arises ; and the horse is thus "foundered." There is a remedy for this condition in dividing the nerve across, before it reaches the foot ; the consequence of which operation is, that the horse, instead of moving with timid steps, puts out his feet freely, and the lameness is cured. If, however, we were to receive the statement thus barely, the fact would militate against our con-

clusion that mechanical provision and sensibility go together, and that they are equally necessary to the perfection of the instrument. We must take into consideration this leading fact, that pressure against the sole and crust is necessary to the play of the foot and to its perfection. When this part becomes inflamed, the animal does not put its foot freely down, nor does it bear its weight upon the hoof so as to bring all the parts into action; hence contraction is produced, the most common defect, as we before said, of the horse's hoof. When the animal is relieved from pain by the division of the nerve, it uses the foot freely, and use restores all the natural actions of this fine piece of mechanism. It is obvious, however, that there is a certain defect; the horse has lost his natural protection, and must now be indebted to the care of his rider. He has not only lost the pain which should guard against over exertion, but the feeling of the ground, which is necessary to his being perfectly safe as a roadster.

The teeth are provided with sensibility much in the same manner as the hoof of the horse is. Although the bone and enamel have no sensibility, yet a branch of a sensible nerve (the fifth) enters into the cavity of every tooth, and the vibration being communicated through the tooth to the nerve, the smallest grain is felt between the teeth.

But, to return to the human hand; in the fingers and palm of a man who uses the fore-hammer, the cuticle is thickened in a remarkable manner. The depressed lines, however, in its inner surface become deeper, and the villi projecting into them longer; which, joined to the aptitude of the cuticle to convey the impression to those included nerves, leaves him in possession of the sense of touch in a very high degree.

In the foot of the ostrich we have a magnified view of the thickened cuticle and the lengthened nerves. This outer skin of its foot almost equals in thickness the hoof of the *solidungula*, and when it is separated from the sensible sole, the villi, or papillæ, having in them the sensible nerves, are withdrawn, leaving corresponding foramina or pores in the sole. We perceive that if the object had been merely to cover and protect the foot, it would have been sufficient to have invested it with a succession of solid and dead layers of cuticle. This would have been the case had the cuticle been merely thickened by pressure, and had there been no design to make a provision adapted in all respects to the habits of the bird.

Such, then, is the structure of the organ of touch: obvious in the extremities of the fingers; magnified in the foot of the horse or of the

ostrich ; and existing even in the delicate skin of the lips.

I have casually noticed that increased vascularity is always an accompaniment of nerves, and necessary to the sensibility of a part. In the museum of the College of Surgeons we see that Mr. Hunter had taken the pains to demonstrate this, by the injection of the blood-vessels of a slug. Although fluid was injected from its heart, the blush from the vermilion extends over its foot ; the foot, in these gasteropoda, being the whole lower flat surface on which the animal creeps. This surface is also the organ of touch, by which it feels and directs its motions. It is on the same principle, if we may compare such things, that we explain the rosy tipped fingers and the ruby lips, which imply fine sensibility combined with high vascularity.

Having described the relation of the cuticle to the nerves of touch, we may take notice of another quality, its roughness, and of the advantages accruing from this. In the first place, as to the subserviency of this quality to feeling, we must be sensible that in touching a finely polished surface the organ is but imperfectly exercised, as compared with its condition when we touch or grasp a rough and irregular body. Had the cuticle been finely polished on its surface, it would have been but ill suited to touch :

on the contrary, it has a very peculiar roughness which adapts it to feeling. A provision for friction, as opposed to smoothness, is a necessary quality of some parts of the skin; thus the roughness of the cuticle has the advantage of giving us a firmer grasp, and a steadier footing. Nothing is so little apt to slip as the thickened cuticle of the hand or foot. In the hoofs of animals, as might be expected, this structure is further developed. The chamois, ibex, or goat, steps securely on the ledges of rocks and at great heights, where it would seem impossible to cling. On the pads or cushions of the cat, the cuticle is rough and granular; and in the foot of the squirrel, indeed of all animals which climb, those pads covered with the peculiar texture of the cuticle, give security in descending, as their claws enable them to grasp and cling.

In concluding this section, we perceive that the organ of touch consists of nerves appropriated to receive the impressions of bodies which are capable of offering resistance. Fine filaments of those nerves, wrapt up in delicate membrane with their accompanying arteries and veins, project from the true skin into corresponding grooves or foramina of the cuticle. They are not absolutely in contact with the cuticle, but are surrounded with a semi-fluid matter. By this fluid and by the cuticle they are protected, at the same time that they are sensible

to the pressure made on the surface, and to cutting, pricking, and heat.* But this capacity, we repeat, is not owing, strictly speaking, to any thing in the structure of the organ, but to the appropriation of the nerve to this class of sensations.

* It is a curious confirmation of the fact, that the cutaneous nerve is adapted to receive impressions from the varieties of temperature, that when disease takes place in the centre of the trunk of a nerve, or when the nerve is surrounded with diseased parts, the sensation of burning accompanies the pain; and the patient refers this to the part of the skin to which the extreme branch of the nerve is distributed. By a burning sensation in the sole of the foot, I have been directed to disease seated in the centre of the thigh.



CHAPTER IX.

OF THE MUSCULAR SENSE.

*Of the Sensibility of the Infant to Impressions,
and the gradual Improvement of the Sense of
Touch.*

A NOTION prevails that the young of animals are directed by instinct, but that there is an exception in regard to the human offspring: that in the child we have to trace the gradual dawn and progressive improvement of reason. This is not quite true; we doubt whether the body would ever be exercised under the influence of reason alone, and if it were not first directed by sensibilities which are innate or instinctive.

The sensibilities and the motions of the lips and tongue are perfect from the beginning; and the dread of falling is shewn in the young infant long before it can have had experience of violence of any kind.

The hand, which is to become the instrument for perfecting the other senses and developing the endowments of the mind itself, is in the infant absolutely powerless. Pain is poetically

described as that power into whose "iron grasp" we are consigned, to be introduced to a material world; now, although the infant is capable of an expression of pain, which cannot be misunderstood, and is the same which accompanies all painful impressions during the whole life, yet it is unconscious of the part of the body which suffers. We have again recourse to the surgeon's experience. There occur certain congenital imperfections which require an operation at this early stage of life; but the infant makes no direct effort with its hand to repel the instrument, or to disturb the dressing, as it will at a period somewhat later.

The lips and tongue are first exercised; the next motion is to put the hand to the mouth, in order to suck it: and no sooner are the fingers capable of grasping, than whatever they hold is carried to the mouth. So that the sensibility to touch in the lips and tongue, and their motions, are the first inlets to knowledge; and the use of the hand is a later acquirement.

The knowledge of external bodies as distinguished from ourselves, cannot be acquired until the organs of touch in the hand have become familiar with our own limbs; we cannot be supposed capable of exploring any thing by the motion of the hand, or of judging of the form or tangible qualities of an object pressed against the skin, before we have a knowledge of our

own body as distinguished from things external to us.

The first office of the hand, then, is to exercise the sensibility of the mouth: and the infant as certainly questions the reality of things by that test, as the dog does by its acute sense of smelling. In the infant, the sense of the lips and tongue is resigned in favour of the sense of vision, only when that sense has improved and offers a greater gratification, and a better means of judging of the qualities of bodies. The hand very slowly acquires the sense of touch, and many ineffectual efforts are seen, in the arms and fingers of the child, before the direction of objects or their distance is ascertained. Gradually the length of the arm, and the extent of its motions become the measure of distance, of form, of relation, and perhaps of time.

Next in importance to the sensibility of the mouth, we may contemplate that sense which is early exhibited in the infant,—the terror of falling. The nurse will tell us that the infant lies composed while she carries it in her arms up stairs; but that it is agitated in carrying it down. If an infant be laid upon the arms and dandled up and down, its body and limbs will be at rest, whilst it is raised; but they will struggle and make an effort, as it descends. There is here the indication of a sense, an innate feeling of danger, the influence of which

we may perceive when the child first attempts to stand or run. When the child is set upon its feet, and the nurse's arms form a hoop around it without touching it, it slowly learns to balance itself and stand; but under a considerable apprehension. Presently, it will stand at such a distance from the nurse's knee, that if it should lose its balance, it can throw itself for protection into her lap. In these its first attempts to use its muscular frame, it is directed by an apprehension which cannot as yet be attributed to experience. By degrees it acquires the knowledge of the measure of its arm, the relative distance to which it can reach, and the power of its muscles. Children, therefore, are cowardly by instinct: they show an apprehension of falling; and we may gradually trace the efforts which they make, under the guidance of this sensibility, to perfect the muscular sense. In the mean time, we perceive how instinct and reason are combined in early infancy: how necessary the first is to existence: how it is subservient to reason: and how it yields to the progress of reason, until it becomes so obscured that we can hardly discern its influence.

When treating of the senses, and showing how one organ profits by the exercise of the other, and how each is indebted to that of touch, I was led to observe that the sensibility of the skin is the most dependant of all on the exercise of

another quality. Without a sense of muscular action or a consciousness of the degree of effort made, the proper sense of touch could hardly be an inlet to knowledge at all. I am now to show that the motion of the hand and fingers, and the sense or consciousness of their action, must be combined with the sense of touch, properly so called, before we can ascribe to it the influence which it possesses over the other organs.

In my general course of lectures on anatomy, I ventured on this explanation from the commencement; much doubting, however, the correctness of my reasoning, from seeing that the great authorities on this subject made no account of the knowledge derived from the motions of our own frame. I called this consciousness of muscular exertion a sixth sense; considering it as essential to the exercise of the sense of touch. I can now refer, in confirmation of this view, to the works of philosophers who have been educated to medicine; and to whom the necessity of the combination of the two faculties had suggested itself as it had to me.* Those distinctions were connected with my enquiries into the functions of the nervous system, and in some measure directed them.†

* See Dr. Brown's Lectures on Moral Philosophy.

† It was this conviction—that we are sensible of the action of the muscles, which led me to the investigation of their nerves; first, by anatomy, and then by experiment. I was finally enabled

The Abbé Nollet, after extolling the sense of touch as superior to all the other senses, and as deserving to be considered the *genus* under which the others should be included as subordinate *species*, makes this remark—" Besides, it
" has this advantage over them, to be at the
" same time both active and passive: for it not
" only puts it in our power to judge of what
" makes an impression upon us, but likewise of

to show that the muscles had two classes of nerves—that on exciting one of these, the muscle contracted: that on exciting the other, no action took place. The nerve which had no power to make the muscle contract was found to be a nerve of sensation. Thus, it was proved that there is a nervous circle connecting the muscles with the brain: that one nerve is not capable of transmitting what is called the nervous spirits, in two different directions at one instant of time; but that for the regulation of muscular action, there is a nerve of sensibility to convey a sensation of the condition of the muscles to the sensorium, as well as a nerve of motion for conveying the mandate of the will to the muscles. In their distribution through the body, the nerves which possess these two distinct powers, of conveying sensation and of exciting the muscles to contraction, are wrapped up, or, as it were, woven together in the same sheath; and they present to the eye the appearance of one nerve. It was only by examining the nerves at their roots, that is, where they arise from different tracts of the brain and spinal marrow, and before they have coalesced, that I succeeded in demonstrating their distinct functions. In the face, the nerve of motion passes by a circuitous course, apart from the nerve of sensation, to be distributed to the muscles; and therefore the distinct characters of these two nerves were more easily proved by experiment than in any other part of the body. See the Philosophical Transactions on the " Nervous Circle which connects the Voluntary Muscles with the Brain," and the " Nervous System." 4to. Longman.

“ what resists our impulsions.” The mistake here lies in giving to the nerves of touch a property which must belong to the actions of muscles. So it is affirmed by physiologists, as I have already had occasion to state, that the sense of touch differs from the other senses by this circumstance—that an effort is propagated towards it, as well as a sensation received from it. This confusion obviously arises from considering the muscular agency, which is directed by the will during the exercise of touch, as belonging to the nerve of touch properly. We proceed to show how the sense of motion and that of touch are necessarily combined.

When a blind man, or a man with his eyes shut, stands upright, neither leaning upon, nor touching aught; by what means is it that he maintains the erect position? The symmetry of his body is not the cause. The statue of the finest proportion must be soldered to its pedestal, or the wind will cast it down. How is it, then, that a man sustains the perpendicular posture, or inclines in due degree towards the winds that blow upon him? It is obvious that he has a sense by which he knows the inclination of his body, and that he has a ready aptitude to adjust it, and to correct any deviation from the perpendicular. What sense then is this? for he touches nothing, and sees nothing; there is no organ of sense hitherto observed

which can serve him, or in any degree aid him. Is it not that sense which is exhibited so early in the infant, in the fear of falling? Is it not the full developèment of that property which was early shown in the struggle of the infant while it yet lay in the nurse's arms? It can only be by the adjustment of muscles that the limbs are stiffened, the body firmly balanced and kept erect. There is no other source of knowledge, but a sense of the degree of exertion in his muscular frame, by which a man can know the position of his body and limbs, while he has no point of vision to direct his efforts, or the contact of any external body. In truth, we stand by so fine an exercise of this power, and the muscles are, from habit, directed with so much precision and with an effort so slight, that we do not know how we stand. But if we attempt to walk on a narrow ledge, or stand in a situation where we are in danger of falling, or rest on one foot, we become then subject to apprehension: the actions of the muscles are, as it were, magnified and demonstrative of the degree in which they are excited.

We are sensible of the position of our limbs; we know that the arms hang by the sides; or that they are raised and held out; although we touch nothing and see nothing. It must be a property internal to the frame by which we thus know the position of the members of our

body : and what can this be but a consciousness of the degree of action, and of the adjustment of the muscles ? At one time, I entertained a doubt whether this proceeded from a knowledge of the condition of the muscles or from a consciousness of the degree of effort which was directed to them in volition. It was with a view to elucidate this, that I made the observations which terminated in the discovery that every muscle had two nerves—one for sensation, and one to convey the mandate of the will and direct its action. I had reasoned in this manner—we awake with a knowledge of the position of our limbs : this cannot be from a recollection of the action which placed them where they are ; it must, therefore, be a consciousness of their present condition. When a person in these circumstances moves, he has a determined object ; and he must be conscious of a previous condition before he can desire a change or direct a movement.

After a limb has been removed by the surgeon, the person still feels pain, and heat, and cold in it. Urging a patient to move who has lost his limb, I have seen him catch at the limb to guard it, forgetful that it was removed ; and long after his loss, he experiences a sensation not only as if the limb remained, but as if it were placed or hanging in a particular position or posture. I have asked a patient—“ Where do

“ you feel your arm now ?” and he has said, “ I feel it as if it lay across my breast,” or that it is “ lying by my side.” It seems also to change with the change of posture of the body. These are additional proofs of a muscular sense ; that there is an internal sensibility corresponding with the changing condition of the muscles ; and that as the sensations of an organ of sense remain after the destruction of the outward organ, so here a deceptious sensibility to the condition of the muscles, as well as to the condition of the skin, is felt after the removal of the limb.

By such arguments I have been in the habit of showing that we possess a muscular sense, and that without it we could have no guidance of the frame. We could not command our muscles in standing, far less in walking, leaping, or running, had we not a perception of the condition of the muscles previous to the exercise of the will. And as for the hand, it is not more the freedom of its action which constitutes its perfection, than the knowledge which we have of these motions, and our consequent ability to direct it with the utmost precision.

The necessity for the combination of two distinct properties of the nervous system in the sense of touch becomes more obvious, if we examine their operation in another but analogous organ ; for example, in the palpa or

tentacula of the lower animals. These animals use those instruments to grope their way: and they consist of a rigid tube containing a pulpy matter, in which there is a branch of a nerve that possesses, in an exquisite degree, the sense of touch. Now when this instrument touches a body and the vibration runs along the pulp of the nerve, the animal can be sensible only of an obstruction: but where is that obstruction, and how is the creature's progress to be directed to avoid it? We must acknowledge that the instrument moves about and feels on all sides, and that it is the action of the muscles moving this projecting instrument, and the sense of their activity, which convey the knowledge of the place or direction of the obstructing body. It appears, therefore, that even in the very lowest creatures, the sense of touch implies the comparison of two distinct senses.

That insects have the most exquisite organs of sense must be allowed: but we do not reflect on the extraordinary accuracy with which in their movements they measure distances. This can only be an adaptation of the muscular exertion to the sense of vision. The spider which I have already alluded to in a former chapter—the *aranea scenica*, when about to leap, elevates itself upon its fore legs, and lifting its head, seems to survey the spot before it jumps. When this insect spies a small gnat or fly upon the wall, it

creeps very gently towards it, with short steps, till it comes within a proper distance, and then it springs suddenly like a tiger. It will jump two feet to seize upon a bee.*

We have a more curious instance of the precision of the eye and of the adaptation of muscular action, in the *chætodon rostratus*.† This fish inhabits the Indian rivers, and lives on



the smaller aquatic flies. When it observes one alighted on a twig, or flying near (for it can shoot them on the wing) it darts a drop of water with so steady an aim as to bring the fly down into the water, when it falls an easy prey. These fishes are kept in large vases for amusement, and if a fly be presented on the end of a twig, they will shoot at it with surprising accuracy. In its natural state it will hit a fly at the distance of from three to six feet. The *zeus insidiator*‡ has also the power of forming its mouth into a tube and squirting at flies so as to en-

* Kirby.

† *Chætodon*, a genus of the Acanthopterygii.

‡ Belonging to another genus of the same Order.

cumber their wings and bring them to the surface of the water. Whether led to admire the wonderful power of instinct in these inferior creatures, or the property acquired by our own eye, we must acknowledge here a compound operation.*

The impression of odours on the nerve of smelling is exactly what some would have us to believe the effect of light is on the nerve of vision; and yet, the impression on the nerve of vision alone is sufficient, in their opinion, to inform us of all that we know through the eye. Now of the direction and distance from which odours come we are quite ignorant, until by turning the head and directing the nostrils, and moving this way and that, we make comparison, and discover on which side the smell is strongest on the sense.

The property of motion in the body is, in insects, rendered subservient to smelling, as well as to vision. There can be nothing in the mere exercise of the organ of smelling to direct the insect in its flight. If a piece of carrion be thrown out, the flies approach it,—not in a direct line, but by coming in circles, towards it; and so do the bees, in a garden, when

* In these instances a difficulty will readily occur to the reader; how does the fish judge of position, since the rays of light are refracted at the surface of the water? Does instinct enable it to do this, or is it by experience?

attracted to a flower. They may be seen, at first, flying wide, and then each circle diminishing as they come near, until they at last alight upon the object. It is from the sense of the odour being more acute in one part of the circle, that the next wheel is made; and thus they are directed in their flight, as it were in a line drawn through these circles.

We can judge of the direction of sounds without turning the head, because the strength of vibration is unequal on the two sides of the head, and a comparison is thus made of the two impressions. But when a person is deaf in one ear the operation is difficult; he is often mistaken as to the direction of sounds, and he has more necessity to turn the head and to compare the position of the tube of the ear with the strength of the impressions. Accordingly, in mixed company, where there are many speakers, he appears positively deaf, from the impossibility of distinguishing minutely the direction of sounds.

The last proof of the necessity of the combination of the muscular sense with the sense of contact will be conclusive. The following is not a solitary instance:—

A mother while nursing her infant was seized with a paralysis, attended by the loss of power on one side of her body and the loss of sensibility on the other side. The surprising, and, indeed, the alarming circumstance here was,

that she could hold her child to her bosom with the arm which possessed muscular power, but only as long as she looked to the infant. If surrounding objects withdrew her attention from the state of her arm, the flexor muscles gradually relaxed and the child was in danger of falling. The details of the case do not belong to our present enquiry; but we see here, first, that there are two properties in the arm: which is shown by the loss of the one and the continuance of the other; secondly, that these properties exist through different conditions of the nervous system; and, thirdly, we perceive how ineffectual to the exercise of the limbs is the continuance of the muscular power, without the sensibility which should accompany and direct it.

The property in the hand of ascertaining the distance, the size, the weight, the form, the hardness or softness, the roughness or smoothness of objects, results from there being this combined perception—from the sensibility of the proper organ of touch being combined with the consciousness of the motion of the arm, hand, and fingers. But the motion of the fingers is especially necessary to the sense of touch. These bend, extend, or expand, moving in all directions like palpa, with the advantage of embracing the object, and feeling it on all its sur-

faces, sensible to its solidity and to its resistance when grasped, moving round it and gliding over its surfaces, and, therefore, feeling every asperity, and every the slightest vibration.

THE PLEASURES ARISING FROM THE MUSCULAR SENSE.

The exercise of the muscular frame is the source of much of the knowledge which is usually supposed to be obtained through the organs of the senses; and to this source, also, we must trace some of our chief enjoyments. We may, indeed, affirm that it is benevolently provided that the vigorous circulation of the blood, and, therefore, the healthful condition both of the mind and the body shall result from muscular exertion and the alternations of activity and repose.

The pleasure which arises from the activity of the body is also attended by gratification from the exercise of a species of power—as that which mere dexterity, successful pursuit in the field, or the accomplishment of some work of art may give. This activity is followed by weariness and a desire for rest: and although unattended with any describable pleasure or local sensation, there is diffused through every part of the frame

after fatigue and whilst the active powers are sinking into repose, a feeling almost voluptuous. To this feeling the impatience of rest succeeds; and thus we are urged to the alternations which are necessary to health, and are invited on from stage to stage of our existence.

We owe other enjoyments to the muscular sense. It would appear that in modern times we know comparatively little of the pleasures arising from motion. The Greeks, and even the Romans, studied elegance of attitude and of movement. Their apparel admitted of it, and their exercises and games must have led to it. Their dances were not the result of mere exuberance of spirits and activity; they combined harmony in the motion of the body and limbs, with majesty of gait. They consisted more of the unfolding of the arms than of the play of the feet,—“ Their arms sublime that floated on the air.” The Pyrrhic dances were elegant movements, joined to the attitudes of combat, and performed in correct coincidence with the expression of the music. The spectators in their theatres must have had very different associations from ours, to account for the national enthusiasm arising from music and their rage excited by a mere error in the time.

This may remind us that the divisions in music in some degree belong to the muscular sense. A man will put down his staff in regu-

lated time, and the sound of his steps will fall into a measure, in his common walk. A boy striking the railing in mere wantonness, will do it with a regular succession of blows. This disposition of the muscular frame to put itself into motion with an accordance to time is the source of much that is pleasing in music, and aids the effect of melody. There is thus established the closest connection between the enjoyments of the sense of hearing and the exercise of the muscular sense.*

* To learn how much the enjoyment of the sense of vision belongs to motion, see the "Additional Illustrations," at the end of the volume.



CHAPTER X.

THE HAND NOT THE SOURCE OF INGENUITY OR
CONTRIVANCE, NOR CONSEQUENTLY OF MAN'S
SUPERIORITY.

SEEING the perfection of the hand, we can hardly be surprised that some philosophers should have entertained the opinion with Anaxagoras, that the superiority of man is owing to his hand. We have seen that the system of bones, muscles, and nerves of this extremity is

suited to every form and condition of vertebrated animals; and we must confess that it is in the human hand that we have the consummation of all perfection as an instrument. This, we perceive, consists in its power, which is a combination of strength with variety and extent of motion; we see it in the forms, relations, and sensibility of the fingers and thumb; in the provisions for holding, pulling, spinning, weaving, and constructing; properties which may be found in other animals, but which are combined to form this more perfect instrument.

In these provisions, the instrument corresponds with the superior mental capacities, the hand being capable of executing whatever man's ingenuity suggests. Nevertheless, the possession of the ready instrument is not the cause of the superiority of man, nor is its aptness the measure of his attainments. So, we rather say with Galen—that man had hands given to him because he was the wisest creature, than ascribe his superiority and knowledge to the use of his hands.*

This question has arisen from observing the

* *Ita quidem sapientissimum animalium est homo: ita autem et manus sunt organa sapienti animali convenientia. Non enim quia manus habuit propterea est sapientissimum, ut Anaxagoras dicebat: sed quia sapientissimum erat, propter hoc manus habuit, ut rectissime censuit Aristoteles. Non enim manus ipsæ homines artes docuerunt, sed ratio. Manus autem ipsæ sunt artium organa: sicut lyra, musici, et forceps, fabri.*

perfect correspondence between the propensities of animals and their forms and outward organization. When we see a heron standing by the water side, still as a grey stone, and hardly distinguishable from it, we may ascribe this habit to the acquired use of its feet, constructed for wading, and to its long bill and flexible neck; for the neck and bill are as much suited to its wants as the liester is to the fisherman. But there is nothing in the configuration of the black-bear particularly adapted to catch fish; yet he will sit on his hinder extremities by the side of a stream, in the morning or evening, like a practised fisher; there he will watch, so motionless as to deceive the eye of the Indian, who mistakes him for the burnt trunk of a tree; and with his fore paw he will seize a fish with incredible celerity. The exterior organ is not, in this instance, the cause of the habit or of the propensity; and if we see the animal in possession of the instinct without the appropriate organ, we can the more readily believe that, in other examples, the habit exists with the instrument, although not through it.

The canine teeth are not given without the carnivorous appetite, nor is the necessity of living by carnage joined to a timid disposition; but boldness and fierceness, as well as cunning, belong to the animal with retractile claws and

sharp teeth, and which prey on living animals.* On the other hand, the propensities of the timid vegetable feeder are not produced by the erect ears and prominent eyes: though his suspiciousness and timidity correspond with them. The boldness of the bison or buffalo may be as great as that of the lion; but the impulse is different—there is a direction given to them by instinct to strike with their horns: and they will so push whether they have horns or not. “The young calf will butt against you before he has horns,” says Galen: and the Scotch song has it, “the putting cow is ay a doddy,” that is, the humble cow (*inermis*), although wanting horns, is always the most mischievous. When that noble animal, the Brahmin bull, of the Zoological Gardens, first put his hoof on the sod and smelt the fresh grass after his voyage,—placid and easily managed before, he became excited, plunged, and struck his horns into the earth, and ploughed up the ground on alternate sides, with a very remarkable precision. This was his dangerous play; just as the dog, in his gambols, worries and fights: or the cat, though pleased, puts out its claws. It would, indeed,

* In some of the quadrumana, the canine teeth are as long and sharp as those of the tiger—but in them they are only instruments of defence, and have no relation to the appetite, or mode of digestion, or internal organization.

be strange, where all else is perfect, if the instinctive character or disposition of the animal were at variance with its arms or instruments.

But the idea may still be entertained that the accidental use of the organ may conduce to its more frequent exercise and to the production of a corresponding disposition. Such an hypothesis would not explain the facts. The late Sir Joseph Banks, in his evening conversations, told us that he had seen, what many perhaps have seen, a chicken catch at a fly whilst the shell stuck to its tail. Sir Humphrey Davy relates that a friend of his, having discovered under the burning sand of Ceylon the eggs of an alligator, had the curiosity to break one of them; when a young alligator came forth, perfect in its motions and in its passions; for although hatched under the influence of the sunbeams, in the sand, it made towards the water, its proper element: when hindered, it assumed a threatening aspect and bit the stick presented to it. As propensities to certain motions, to which their external organs are subservient, are implanted in animals, so are passions given as the means of their defence or of obtaining food. But this has been well said seventeen hundred years ago. "Take," says Galen, "three eggs, one of an eagle, another of a goose, and a third of a viper; and place them favourably

“ for hatching. When the shells are broken,
“ the eaglet and the gosling will attempt to fly ;
“ while the young of the viper will coil and
“ twist along the ground. If the experiment be
“ protracted to a later period, the eagle will
“ soar to the highest regions of the air, the goose
“ betake itself to the marshy pool, and the viper
“ will bury itself in the ground.”

We have, daily, before us the proofs of ingenuity in the arts, not only surviving the loss of the hand, but excited and exercised where there were no such instruments from birth. What is more surprising than to see the feet, in such individuals becoming substitutes for the hands, and working minute and curious things? Unfortunately too, the most diabolical passions will in some natures be developed, and crimes committed where we might have supposed it impossible, from the power of execution being denied. Of this the most remarkable instance was in a man who from birth had no arms, like the unfortunate youth described in the early part of the volume, but who, as if possessed of a devil, had committed many murders before he was discovered and executed. This wretch was a beggar, who took his stand on the high way some miles from Moscow, on the skirts of a wood. His manner was to throw his head against the stomach of the person who was in the act of

giving him charity, and having stunned him, to seize him with his teeth and so drag him into the wood !

But to turn to a more agreeable part of our subject. With the possession of an instrument like the hand, there must be a great part of the organization which strictly belongs to it, concealed. The hand is not a thing appended, or put on, like an additional movement in a watch ; but a thousand intricate relations must be established throughout the body in connection with it ; such as nerves of motion and nerves of sensation : there must be an original part of the composition of the brain which shall have relation to these new parts, before they can be put into activity : and even with all this superadded organization, the hand would lie inactive, unless there were created a propensity to put it into operation.

Voltaire has said that Newton, with all his science, knew not how his arm moved ! So true it is that all such studies have their limits. But, as he acknowledges, there is a wide difference between the ignorance of the child or of the peasant, and the consciousness of the philosopher that he has arrived at a point beyond which man's faculties do not carry him. We may add, is it nothing to have the mind awakened to the many proofs of design in the hand—to be brought to the conviction that every

thing is orderly and systematic in its structure, —that the most perfect mechanism, the most minute and curious apparatus, and sensibilities the most delicate and appropriate, are all combined in operation that we may move the hand? What the first impulse to motion is we do not know, nor how the mind is related to the body; yet it is important to know with what extraordinary contrivance and perfection of workmanship the bodily apparatus is placed between that internal faculty which impels us to use it and the exterior world.

I have been asked by men of the first education and talents whether any thing really deficient had been discovered in the organs of voice in the orang-outang to prevent him from speaking? The reader will give me leave to place this matter correctly before him. In speaking, there is first required a certain force of expired air, or an action of the whole muscles of respiration; in the second place, the vocal chords, in the top of the wind-pipe, must be drawn into accordance by their muscles, else no vibration will take place, and no sound issue; thirdly, the open passages of the throat must be expanded, contracted, or extended by their numerous muscles, in correspondence with the condition of the vocal chords or glottis; and these must all sympathize before even a simple sound is produced. But to articulate that sound, so that it may be-

come a part of a conventional language, there must be added an action of the pharynx, of the palate, of the tongue and lips. The exquisite organization for all this is not visible in the organs of the voice, as they are called : it is to be found in the nerves which combine all these various parts in one simultaneous act. The meshes of the spider's web, or the cordage of a man-of-war, are few and simple compared with the concealed filaments of nerves which move these parts ; and if but one be wanting, or its tone or action disturbed in the slightest degree, every body knows how a man will stand with his mouth open, twisting his tongue and lips in vain attempts to utter a word.

It will now appear that there must be distinct lines of association suited to the organs of voice—different to combine them in the bark of a dog, in the neighing of a horse, or in the shrill whistle of the ape. That there are wide distinctions in the structure of the different classes of animals is most certain ; but independently of those which are apparent, there are secret and minute varieties in the associating cords. The ape, therefore, does not articulate—First, because the organs are not perfect to this end. Secondly, because the nerves do not associate these organs in that variety of action which is necessary to speech. And, lastly, were all the

exterior apparatus perfect, there is no impulse to that act of speaking.

Now I hope it appears, from this enumeration of parts, that the main difference lies in the internal faculty or propensity. As soon as a child can distinguish and admire, then are its features in action; its voice begins to be modified into a variety of sounds; these are taken up and repeated by the nurse, and already a sort of convention is established between them. The perfect correspondence is a contrivance; but the source of the articulation, that which prompts to the first efforts, is in our intellectual nature. We cannot, therefore, doubt that a propensity is created in correspondence with the outward organs, without which they would be useless appendages. The aptness of the instrument or external organ will undoubtedly improve the faculty—just as we find that giving freedom to the expression of passion adds force to the emotion in the mind.*

* One cannot but reflect here on that grand revolution which took place when language, till then limited to its proper organ, had its representation in the work of the hand. Now that a man of mean estate can have a library of more intrinsic value than that of Cicero, when the sentiments of past ages are as familiar as those of the present, and the knowledge of different empires is transmitted and common to all, we cannot expect to have our sages followed, as of old, by their five thousand scholars. Nations will not now record their acts by building pyramids, or by

· On this, as upon many other occasions, there may be an argument against the further multiplication of proofs in favour of natural religion. It may be said that we vary the instances without making the proofs stronger. Now certainly there can be no higher argument in favour of the perfection of design, than the simple fact, that two intellectual beings can breathe out their thoughts, and hold communion on the subject of the ideas that arise in their minds. The knowledge of the means, and of the intricate organs by which voice is produced, can indeed add nothing to our wonder, or to the force of our conviction, that all that regards man's state is ordered in perfection. So it may be a thing as admirable, if philosophically considered, that we can raise the arm by willing it, as when we know all the relations of nerves and muscles, and bones and joints, through which it is accomplished. But I would ask who thinks of this, or who feels emotion, while he speaks or moves his hand? Do these actions excite either admiration or gratitude, and do we not require to be brought to consider these operations anew? Is

consecrating temples and raising statues, once the only means of perpetuating great deeds or extraordinary virtues. It is in vain that our artists complain that patronage is withheld: for the ingenuity of the hand has at length subdued the arts of design — printing has made all other records barbarous, and great men build for themselves a “livelong monument.”

it not agreeable to know how the actions are performed, and is it not important that the emotions of surprise and gratitude thus excited should be repeated and enforced, until they become an enduring devotional feeling? In fine, whilst it is pleasing to reflect that the great authorities in natural science in times past have entertained the belief of the great Architect, and of the continuance of his government, it cannot be without its use to add strength to the same belief, from the improvements that are daily making in all departments of knowledge.

We must not omit to speak of the hand as an instrument of expression. Formal dissertations have been written on this. But were we constrained to seek authorities, we might take the great painters in evidence; since by the position of the hands, in conformity with the figure, they have expressed every sentiment. Who, for example, can deny the eloquence of the hands in the *Magdalens of Guido*: their expression in the cartoons of *Raphael*: or in the *Last Supper*, by *Leonardo da Vinci*? We see there expressed all that *Quintilian* says the hand is capable of expressing.—“For other parts of the body, says he, assist the speaker, but these, I may say, speak themselves. By them we ask, we promise, we invoke, we dismiss, we threaten, we intreat, we deprecate, we express fear, joy, grief,

our doubts, our assent, our penitence : we show moderation, profusion, we mark number and time. “ *Nam ceteræ partes loquentem adjutant, hæ, prope est ut dicam, ipsæ loquuntur. His poscimus, pollicemur, vocamus, dimittimus, minamur, supplicamus, abominamur, timemus; gaudium, tristitiam, dubitationem, confessionem, penitentiam, modum, copiam, numerum, tempus, ostendimus, &c.*”

Buffon has attempted to convey to us the mode in which knowledge may have been originally acquired, by watching (in fancy) the newly awakened senses in the first created Man. But, for that which is consistent and splendid in our great poet—who makes Man raise his wondering eyes to Heaven and spring up by quick instinctive motion as “ *thitherward endeavouring,*” Buffon substitutes a bad combination of philosophy with eloquence.

“ *To place the subject more distinctly before us,*” says Buffon, “ *the first created man shall speak for himself.*” The sentence which he is made to utter is to the effect,—“ *that he remembers the moment of his creation—that time, so full of joy and trouble, when he first looked round on the verdant lawns and crystal fountains, and saw the vault of Heaven over his head;*”—and he proceeds to declare,—“ *that he*

knew not what he was or whence he came, and believed that all he saw was part of himself." He is thus represented to be conscious of objects, which even to see implies experience, and to enjoy, supposes a thousand agreeable associations already formed:—but from this blissful state he is awakened by striking his head against a palm tree, which he had not yet learned could hurt him!

Men are diffident of their first notions, and conceive that philosophy must lead to something very different from what they have been early taught. Hence the absurdity of this combination of philosophy and poetry.

Later writers have argued that we have no right to suppose that there has been, at any time, an interruption to the uniform course of nature. What they term the uniformity of nature, is the prevalence of the same laws which are now in operation. If, say they, it were found that on the arrival of a colony in a new country, fruits were produced spontaneously around them, and flowers sprung up under their feet, then, we might suppose that our first parents were placed in a scene of profusion and beauty—suited to their helpless condition—and unlike what we see now in the course of nature. It is not very wise to entertain the subject at all; but if it is to be argued, this is starting altogether wide of the question. We do not

desire to know how a whole tribe migrating westward could find sustenance,—but in what state man could be created to live without a deviation from what is called the course of nature.

If man had been formed helpless as an infant, he must have perished. And if mature in body, he must have been created with faculties suited to his condition. A human being, pure from the Maker's hands, with desires and passions implanted in him, adapted to his state, and with a suitable theatre of existence, implies something very near what we have been early taught to believe.

In every change which the globe has undergone, we see an established relation between the animal created, and the elements around. It is idle to suppose this a matter of chance. Either the structure and functions of the animal must have been formed to correspond with the condition of the elements, or the elements must have been controlled to minister to the necessities of the animal; and if the most careful investigation lead us to this conclusion, in contemplating all the inferior gradations of animal existence, what is it that makes us so unwilling to admit such an influence in the last grand work of creation?

We cannot resist those proofs of a beginning, or of design prevailing every where, or of a First

Cause. When we are bold enough to extend our enquiries into the great revolutions which have taken place, whether in the condition of the earth or in the structure of the animals which have inhabited it, our notions of the "uniformity" of the course of nature must suffer some modification. Changes must, at certain epochs, have been wrought, and new beings brought into existence, different from the order of things previously existing, or now existing. Such interference is not contrary to the great scheme of creation. It is not contrary to that scheme, but only to our present state. For the most wise and benevolent purposes, a conviction is implanted in our nature that we should rely on the course of events, as permanent and necessary. We belong to a certain epoch; and it is when our ambitious thoughts carry us beyond our natural condition, that we feel how much our faculties are constrained, and our conceptions, as well as our language, imperfect. We must either abandon these speculations altogether, or cease to argue purely from our present situation.

It has been made manifest that man and the animals inhabiting the earth have been created with reference to the magnitude of the globe;—that their living endowments bear a relation to their state of existence and to the elements around them. We have learnt that the system

of animal bodies is simple and universal, notwithstanding the amazing diversity of forms that meet the eye—and that this system not only embraces all living creatures, but that it has been continued from periods of great antiquity, before the last revolution of the earth's surface had been accomplished. The most obvious appearances and the labours of the geologist give us reason to believe that the earth has not always been in the state in which it is now presented to us. Every substance which we see is compound ; we nowhere obtain the elements of things : the most solid materials of the globe are formed of decomposed and reunited parts. Changes have been wrought on the general surface, and the proofs of these changes are as distinct as the furrows on a field are indicative that the plough has passed over it. The deeper parts of the crust of the earth and the animal remains imbedded, also give proofs that in the course of these revolutions there have been long periods or epochs. In short, progressive changes, from the lowest to the highest state of existence, of organization and of enjoyment, point to the great truth that there was a beginning.

When the geologist sees a succession of stratified rocks—the lowest simple, or perhaps chemical ; the strata above these, compound ; and others more conglomerated, or more distinctly

composed of the fragments of the former—it is not easy to contradict the hypothesis of an eternal succession of causes. But there is nothing like this in the animal body; the material is the same in all, the general design too is the same: but each family, as it is created, is submitted to such new and fundamental arrangements in its construction as implies the presence of the hand of the Creator.

There is nothing in the inspection of the species of animals, which countenances the notion of a return of the world to any former condition. When we acknowledge that animals have been created in succession and with an increasing complexity of parts, we are not to be understood as admitting that there is here proof of a growing maturity of power, or an increasing effort in the Creator: and for this very plain reason, which we have stated before, that the bestowing of life or the union of the vital principle with the material body, is the manifestation of a power superior to that displayed in the formation of an organ or the combination of many organs, or construction of the most complex animal mechanism. It is not, therefore, a greater power that we see in operation, but a power manifesting itself in the perfect and successive adaptation of one thing to another—of vitality and organization to inorganic matter.

In contemplating the chain of animal creation,

we observe that even now there are parts of the earth's surface which are marshy, and insalubrious; and that these are the places inhabited by amphibious and web-footed animals,—such as are suited to the oozy margins of swamps, lakes, or estuaries. It is most interesting to find that when the remains of animals, of similar construction, are found in the solid rocks, the geologist discovers, by other signs, that at the period of the formation of these rocks, the surface was flat, and that it produced such plants as imply a similar state of the earth to these swampy and unhealthy regions.

We thus mark changes in the earth's surface, and observe, at the same time, corresponding changes in the animal creation. We remark varieties in the outward form, size, and general condition of animals, and corresponding varieties in the internal organization,—until we find Man created, of undoubted pre-eminence over all, and placed suitably in a bounteous condition of the earth.

Most certainly the original crust of the earth has been fractured and burst up, that its contents might be exposed; that they might be resolved and washed away, by the vicissitudes of heat, cold, and rain: mountains and valleys have been formed; the changes of temperature in the atmosphere have ensured continual motion

and healthful circulation : the plains have been made salubrious, and the damps which hung on the low grounds have gathered on the mountains in clouds, so that refreshing showers have brought down the soil to fertilize the plain. In this manner have been supplied the means necessary for man's existence, and objects suited to excite his ingenuity, and to reward it, and fitted to develop all the various properties both of his body and of his mind. And thus it is "that the invisible things from the creation of the world are perceived by what we do see."

There is extreme grandeur in the thought of an anticipating or prospective intelligence : in reflecting that what was finally accomplished in man, was begun in times incalculably remote, and antecedent to the great revolutions which the earth's surface has undergone. Nor are these conclusions too vast to be drawn from the examination of a part so small as the bones of the hand ; since we have shown that the same system of parts which constitutes the perfection of that instrument adapted to our condition, had its type in the members of those vast animals which inhabited the bays, and inland lakes of a former world. If we seek to discover the relations of things, how sublime is the relation established between that state of the earth's surface, which has resulted from a long succes-

sion of revolutions, and the final condition of its inhabitants as created in accordance with these changes.

Nothing is more surprising to our measure of time, than the slowness with which the designs of Providence have been fulfilled. But as far as we can penetrate by the light of natural knowledge, the condition of the earth, and with it of man's destinies, have hitherto been accomplished in great epochs.

We have been engaged in comparing the structure, organs, and capacity of man and of animals; we have traced a relation; but we have also observed a broad line of separation between them—man alone capable of reason, affection, gratitude, and religion: sensible to the progress of time, conscious of the decay of his strength and faculties, of the loss of friends, and the approach of death.

One who was the idol of his day has recorded his feelings on the loss of his son, in nearly these words,—“ We are as well as those can be who have nothing further to hope or fear in this world. We go in and out, but without the sentiments that can create attachment to any spot. We are in a state of quiet, but it is the tranquillity of the grave, in which all that could make life interesting to us is laid.” If in such a state, there were no refuge for the mind, then were there something wanting in the scheme of

nature:—an imperfection in man's condition at variance with the benevolence which is manifested in all other parts of animated nature.

I have sometimes thought it possible, that a greatly extended survey of nature may humble too much our conceptions of ourselves; and that this requires to be corrected by the study of things more minute, and in which we are more directly concerned: by dwelling on the perfection of the frame of the animal body and the marvellous endowments of the living properties. When we have formed some estimate of the immensity of the heavenly bodies, we are struck with admiration in following the successive advances made in the science:—an improvement in the curves of the glasses of the telescope, a new mode of polishing the reflecting surfaces, a change in the chemical composition of the glasses, or a more perfect adjustment of their dispersive powers—leads to the discovery of circle beyond circle of worlds interminably. We fan the imagination and labour to comprehend the immensity of the creation, and fall back with the impression of the littleness of all that belongs to us: our lives seem but a point of time, compared with the astronomical and geological periods, and we ourselves, as atoms, driven about, amidst unceasing changes of the material world.

But it has been shown, that whether we take the animal body as a single machine, or embrace in the survey the successive creation of animals, conforming always to the improving condition of the earth, there is nothing like chance or irregularity in the composition of the system. In proportion indeed as we comprehend the principles of mechanics, or of hydraulics, as applicable to the animal machinery, we shall be satisfied of the perfection of the design. If anything appear disjointed or thrown in by chance, let the student mark that for contemplation and experiment, and most certainly, when it comes to be understood, other parts will receive the illumination, and the whole design stand more fully disclosed.

The extension of knowledge has not necessarily the effect of raising the mind to more consolatory contemplations. We may quote the ancient philosopher in contrast with the modern. The former, having nothing in his mind to draw him from observing the just relations of human beings to the world, but, on the contrary, seeing every thing suited to man or subordinate, thinks of him "as a little God harboured in a humane body." But when by science, and the aid of instruments, or "the ingenuity of the hand," vision is extended to things too remote perhaps, or too minute, to fall within our natural sphere; when instead of the extended plane, and visible

horizon of the stable earth, our globe is thought of as a ball rolling through space, amidst myriads besides, greater than it: the expression is excusable that—"the earth with man upon it does not seem much other than an ant-hill, where some ants carry corn, and some carry their young, and some go empty, and all to and fro, a little heap of dust."

We may consider man, before the lights of modern philosophy had their influence on his thoughts, as in a state more natural; in as much, as he yielded unresistingly to those sentiments which directly flow from the objects and phenomena around him. But when that period of society arrived, in which he made natural phenomena the subjects of experiment or of philosophical enquiry, then was there some danger of a change of opinion, not always beneficial to his state of mind. This danger does not touch the philosopher so much as the scholar. He who has strength of mind and ingenuity to make investigations into nature, will not be satisfied with the discovery of secondary causes—his mind will be enlarged, and the objects of his thoughts and aspirations become more elevated. But it is otherwise with those not themselves habituated to investigation, and who learn, at second hand, the result of those enquiries. If such a one sees the fire of heaven brought down into a phial, and materials com-

pounded, to produce an explosion louder than the thunder, and ten times more destructive, the storm will no longer speak an impressive language to him. When in watching the booming waves of a tempestuous sea along the coast, he marks the line at which the utmost violence of the ocean is stemmed, and by an unseen influence thrown back, he is more disposed to feel the providence extended to man, than when the theory of the moon's action is, as it were, interposed between the scene which he contemplates, and the sentiments naturally arising in his breast. Those influences on the mind which are natural and just, and beneficently provided, and have served to develop the sentiments of millions before him, are dismissed as things vulgar and to be despised. With all the pride of newly acquired knowledge, his conceptions embarrass, if they do not mislead him; in short, he has not had that intellectual discipline, which should precede and accompany the acquisition of knowledge.

But a man, possessed of genius of the highest order, may lose the just estimate of himself, from another cause. The sublime nature of his studies may consign him to depressing thoughts. He may forget the very attributes of his mind, which have privileged these high contemplations, and the ingenuity of the hand, which has so extended the sphere of his observation.

The remedy, to such a mind, is in the studies which we are enforcing. The heavenly bodies, in their motions through space, are held in their orbits by the continuance of a power, not more wonderful or more deserving of admiration, than that by which a globule of blood is suspended in the mass of fluids—or by which, in due season, it is attracted and resolved: than that, by which a molecule entering into the composition of the body, is driven through a circle of revolutions and made to undergo different states of aggregation: becoming sometime, a part of a fluid, sometime, an ingredient of a solid, and finally cast out again, from the influence of the living forces.

Our argument, in the early part of the volume, has shown man, by the power of the hand (as the ready instrument of the mind) accommodated to every condition through which his destinies promise to be accomplished. We first see the hand ministering to his necessities, and sustaining the life of the individual. In a second stage of his progress, we see it adapted to the wants of society, when man becomes a labourer and an artificer. In a state still more advanced, science is brought in aid of mechanical ingenuity, and the elements which seemed adverse to the progress of society, become the means conducing to it. The seas, which at first set

limits to nations, and grouped mankind into families, are now the means by which they are associated. Philosophical chemistry has subjected the elements to man's use; and all tend to the final accomplishment of the great objects to which every thing, from the beginning, has pointed—the multiplication and distribution of mankind, and the enlargement of the sources of man's comfort and enjoyment—the relief from too incessant toil, and the consequent improvement of the higher faculties of his nature. Instinct has directed animals, until they are spread to the utmost verge of their destined places of abode. Man too is borne onwards; and although, on consulting his reason, much is dark and doubtful, yet does his genius operate to fulfil the same design, enlarging the sphere of life and enjoyment.

Whilst we have before us the course of human advancement, as in a map, we are recalled to a nearer and more important consideration: for what to us avail all these proofs of divine power—of harmony in nature—of design—the predestined accommodation of the earth, and the creation of man's frame and faculties, if we are stopped here? If we perceive no more direct relation between the individual and the Creator? But we are not so precluded from advancement. On the contrary, reasons accumulate at every step, for a higher estimate of the living soul, and

give us assurance that its condition is the final object and end of all this machinery, and of these successive revolutions.

To this, must be referred the weakness of the frame, and its liability to injury, the helplessness of infancy, the infirmities of age, the pains, diseases, distresses, and afflictions of life—for by such means is man to be disciplined—his faculties and virtues unfolded, and his affections drawn to a spiritual Protector.



ADDITIONAL ILLUSTRATIONS.

ADDITIONAL ILLUSTRATIONS.

THE MECHANICAL PROPERTIES OF THE SOLID STRUCTURE OF THE ANIMAL BODY CONSIDERED.

It has been shown in the first chapter that solidity and gravity are qualities necessary to every inhabitant of the earth ; the first to protect it ; the second, that the animal may stand, and possess that resistance, which shall make the muscles available for action.

The first material to be taken notice of, which bestows this necessary firmness on the animal textures, is the *cellular substance*. This consists of delicate membranes, which form cells ; these cells communicate with each other, and the tissue thus composed enters every where into the structure of the animal frame. It constitutes the principal part of the *medusa*, which floats like a bubble on the water ; and it is found in every texture of the human body. It forms the most delicate coats of the eye ; and gives toughness and firmness to the skin. It is twisted into ligaments, and knits the largest bones : it is the medium between bone, muscle, and blood-vessel : it produces a certain

firmness and union of the various component parts of the body while it admits of their easy motion. Without it, we should be rigid, notwithstanding the proper organs for motion; and the cavities could not be distended or contracted, nor could the vessels pulsate.

But the cellular texture is not sufficient on all occasions, either for giving strength or protection: nor does it serve to sustain the weight, unless the animal lives suspended in water, or creeps upon the ground. We see, therefore, the necessity for some harder and more resisting material being added, if the weight is to rest on points or extremities; or if the muscular activity is to be concentrated.

Nature has other means of supplying the fulcrum and lever, besides the bones, or true skeleton, which we have been examining in the first part of this volume: and perhaps we shall find that there may be a system of solid parts superior to what we have been studying in the *vertebrata*.

The larvæ of proper insects and the annelides have no exterior members for walking or flying: but to enable them to creep, they must have points of resistance, or their muscles would be useless. Their skins suffice; and they are hardened by a deposit within them, for this purpose. But if this skin were not further provided, it would be rigid and unyielding, and be no sub-

stitute for bone. These hardened integuments are, therefore, divided into rings; to these the muscles are attached; and as the cellular membrane between the rings is pliant, these annelids can creep and turn in every direction.

Without further argument, we perceive how the skin, by having a hard matter deposited in it, is adapted to all the purposes of the skeleton. It is worthy of notice that some animals, still lower in the scale,—the tubipores, sertularia, cellularia, &c. exhibit something like a skeleton. They are contained within a strong case, from which they can extend themselves; whilst the corals and madrepores, on the other hand, have a central axis of hard material, the soft animal substance being, in a manner, seated upon it. But these substitutes for the skeleton are, like shell, foreign to the living animal; although in office they may resemble bone, in sustaining the softer substance and giving form.

In the proper insect I should say that there is a nearer approach to a skeleton, were it not that the apparatus is more perfect than in some of the animals which have a true skeleton. The resisting material is here deposited externally: and is converted to every purpose which we have seen attained by means of the skeleton. Distinct members are formed, with the power of walking, leaping, flying, holding, spinning, and weaving. The hardened integuments, thus arti-

culated and performing the office of bones, have, like them, spines and processes ; with this difference, that their aspect is towards the centre, instead of projecting exteriorly. Were we to compare the system of "resisting parts" in man and in the insect, we should be forced to acknowledge the mechanical provisions to be superior in the lower animal ! The first advantage of the skeleton (as we may be permitted to call the system of hard parts in the insect) being external and lifeless, is, that it is capable of having greater hardness and strength bestowed upon it, according to the necessities of the animal, than can be bestowed upon bone ; true bone, being internal and growing with the animal, is penetrated with blood vessels ; and therefore must be porous and soft. The next advantage in the exterior crust or skeleton is mechanical. The hard material is strong to resist fracture, and to bear the action of muscles, in proportion to its distance from the centre : for the muscles in the insect, instead of surrounding the bones, as in the higher animals, are contained within the shell, and the shell is, consequently, so much the further thrown off from the axis of the limb.

When considering the larger vertebral animals, we had reason to say that there is a correspondence between the resistance of the bones and the power of the muscles ; and we may indulge the same reflection here. As the

integument covering the insect is much harder than bone, so are the muscles stronger, compared with the muscles of the vertebrata. From the time of Socrates, comparisons have been made between the strength of the horse and of the insect; to the obvious superiority of the latter.

As goodly a volume has been written on the muscles of a caterpillar as has ever been dedicated to the human myology. A very minute anatomical description has been made of the caterpillar which feeds upon the willow; and here we see that the annular construction of the hard integument determines the plan of the whole anatomy: the arrangement of the muscles, and the distribution of the nerves. Each ring has its three sets of muscles; direct, oblique, traversing and interweaving, but yet distinct and symmetrical; and all as capable of being minutely described as those of the human body have been by Albinus.* Corresponding with these muscles, the system of nerves is delicately laid down. In short, we allow ourselves to be misled in supposing that animals, either of minute size or low in the scale of arrangement, exhibit any neglect or imperfection. Even if they were more simple in structure, the admiration should be the greater: since they have all

* The work referred to is by Lyonnet, who reckons four thousand and sixty one muscles in this caterpillar.

the functions in full operation which are necessary to life.

We may perceive that a certain substance calculated to sustain the more strictly living part, and to give strength, may be traced through all living bodies. In the vegetable it is the woody fibre; and there, sometimes, as if to mark the analogy, we may find silicious earth deposited instead of the phosphate and carbonate of lime of the animal structure. In the lower animals we find membranes capable of secreting a solid material, and although in some instances the substance is like leather or cartilage, it is in general earthy, and for the most part, carbonate of lime. But when elasticity is necessary, as well as general resistance, cartilage is employed, which is a highly compressible and elastic substance. Thus, fishes have a large proportion of cartilage in their bones; and from this greater quantity, some have been called cartilaginous in distinction to the osseous or true fishes. The cartilaginous and elastic skeleton comes into use in an unexpected manner in the fish: when the salmon or trout leaps from the water, the muscles bend the elastic spine; this recoils in aid of the muscles of the opposite class: and thus these two forces combine to give a powerful stroke with the tail on the water.

MECHANICAL PROPERTIES OF BONE OR OF THE
TRUE SKELETON.

These considerations lead us the more readily to understand the composition of bone. It is combined of three parts having different properties,—membrane, phosphate of lime, and cartilage. By these various substances being united in its texture, it is enabled to resist stretching, compression, and torsion. If bone had a superabundance of the earthy parts, it would break like a piece of porcelain; and if it did not possess toughness and some degree of elasticity, it would not enable a man to pull and push and twist.

Looking to the dense bone, we should hardly suppose that it was elastic. But if ivory be possessed of elasticity, it cannot be denied to bone. Now if a billiard ball be put upon a marble slab which has been painted, a very small spot will mark where the contact has been; but if we let the ball drop upon the marble from a height, we shall find the spot much larger, and that the elasticity of the ivory has permitted the ball to yield and momentarily to assume an oblate spheroidal form.

When a new principle is admitted into a complex fabric, the utmost ingenuity can hardly

anticipate all the results. Elasticity is extensively employed in the machinery of the animal body; and to show how finely it must be apportioned, we shall take the illustration of a bridge built with iron instead of stone, and having a certain swing and elasticity. It lately happened that a bridge of this kind fell, in very curious circumstances,—by the marching of a body of soldiers over it. Now the bridge was calculated to sustain a greater weight than this body of men: and had they walked tumultuously over it, it would have withstood the pressure. But the soldiers marching to time, accumulated a motion, aided by the elasticity of the material, which broke it down. This leads us to form a conception of the necessity of the fine adjustment of the solid material in the animal fabric; not merely to enable it to sustain the incumbent weight, or to resist transverse or oblique impulses, but to withstand the frequent, and regularly repeated forces to which it may be subject in the various actions of the body. It gives interest to this fact, that there is hardly a bone which has not a constitution of its own, adjusted to its place and use: the heel bone, the shin bone, the vertebræ, and the bones of the head, all differ in mechanical construction.

Let us compare the machinery of some complicated engine with the mechanical properties in an animal body, that we may comprehend

what is most truly admirable. Suppose the engineer has contrived a steam carriage. He has with the utmost possible precision calculated the power of the steam, the pressure of the atmosphere, the strength of the tubes and cylinder, the weight to be moved, and the friction of the whole machinery. The engine is designed, every thing is proportioned, and at length it is constructed; but it remains immoveable. After much thought, the impediment is discovered, the pressure is eased, or the friction is diminished, and to the admiration of the beholders the carriage actually moves, till a pipe bursts: but, this is mended, the whole is improved, and a day is appointed for a great trial; the engine now runs for half a mile, and first, a bolt is shaken loose, then a spring snaps; but, at length, with renewed ingenuity and labour and much correction, after a few months, it actually runs a stage. We have here, by comparison, a sort of proof how much there is to admire in the mere machinery of an animal frame, and before the powers of life are measured out to it: such for example as the force of the heart to propel the blood, the resistance of the tubes to the circulating fluids, the strength of the limbs proportioned to the weight of the body, the action of the muscles adapted to the length of the bones, as levers, the flexibility of the joints, the firmness of the bones to resist

pressure or weight; their elasticity to prevent concussion and fracture. In the animal body there is no accident occurring from disproportioned forces,—the active and resisting powers are finely balanced, no second trial is wanted to increase the power, or strengthen the levers, or add to the elasticity of the springs—it is at once perfect; perfect to its end. But to understand this fully, and the adaptations in the constitution of the bones, we must proceed a little deeper in our investigation.

Perfect security against accidents in the animal body, and in man especially, is not consistent with the scheme of nature. Without the precautions and the continued calls to exertion, which danger and the uncertainty of life produce, many of the faculties of the mind would remain unexercised. Whence else would come courage, resolution, and all the manly virtues? Take away the influence of the uncertain duration of life, and we must suppose also a change in the whole moral constitution of man. Whether we consider the bones as formed to protect important organs, as in the skull: or to be levers to which the muscles are attached, as in the limbs: or in both capacities, as in the texture of the chest: while they are perfectly adapted to their function, they are yet subject to derangements from accident. The mechanical adaptations are perfectly sufficient to their ends; and

afford safety in the natural exercises of the body. To these exercises there is an intuitive impulse, ordered with a relation to the frame of the body; whilst, on the other hand, we are deterred from the excessive or dangerous use of the limbs by the admonitions of pain. Without such considerations, the reader would fall into the mistake that weakness and liability to fracture implied imperfection in the frame of the body: whereas a deeper contemplation of the subject will convince him of the incomparable perfection both of the plan and of the execution. The body is intended to be subject to derangement and accident; and to become, in the course of life, more and more fragile, until by some failure in the frame-work or vital actions, life terminates.

The bones of the extremities are called hollow cylinders. Now, after having convinced ourselves of the necessity of this formation, which combines strength with lightness, we may find, upon a more particular examination, that these bones are extremely varied in their shapes: and we are, at least, prone to believe that there is much of chance or irregularity in their forms. But such a conception is quite inconsistent with a correct knowledge of the skeleton. As this notion, however, is very commonly entertained and leads to further mistakes, we shall take pains to show,—first, why the bones are hollow

cylinders ; and, in the second place, why they vary in their shape, so as to appear to the superficial observer irregular.

The reasoning that applies to the hollow cylindrical bone serves equally to explain the admirable structure of many other natural forms, as that of a quill, a reed, or a straw. The last example reminds us of the unfortunate man who was drawn from his cell before the Inquisition, and accused of having denied that there was a God ; when, picking up a straw that had stuck to his garments, he said, “ If there were nothing “ else in nature to teach me the existence of a “ Deity, this straw would be sufficient.”

It hardly requires demonstration to prove that, with a given mass of material to make a pillar or column, the hollow cylinder will be the form of strength. The experiments of Du Hamel on the strength of beams afford us the best illustration how the material should be arranged to resist transverse fracture. When a beam rests on its extremities, bearing a weight upon its centre, it admits of being divided into three portions ; for these three parts are in a different condition with regard to the weight. The lower part resists fracture by its toughness : the upper part, by its density and resistance to compression : but there is a portion between these which is not acted upon at all ; which might be taken away without any considerable weakening of the

beam : and which might be added to the upper or the lower part with great advantage. It can readily be understood how a tougher substance added to the lower part would strengthen the beam. We see it in the skin which is laid along the back part of the Indian's bow ; or in the leather of a carriage spring. The following is a beautiful experiment to demonstrate what is the quality in the timber which resists, at the upper portion of the beam. If a portion, amounting to nearly a third part, of the beam be cut away, and a harder piece of wood be nicely let into the space, the strength will be increased ; because the hardness of this piece of wood resists compression. This experiment I like the better because it explains a very interesting peculiarity in the different densities of the several parts or sides of the bones.

In reading anatomical books, we are led to suppose that the various forms of the bones result from the pressure of the muscles which surround them. This is a mistake. Were we to consider this as the true explanation, it would not only be admitting an imperfection, but we should expect to find, if the bones yielded in any degree to the force of the muscles, that they would yield more and more, and be ultimately destroyed. There is nothing more admirable in the living frame than the relation established between the muscular power and the strength or

capacity of passive resistance in the bones. The deviations from the cylindrical forms are not irregularities; and if we take that bone which deviates the furthest from the cylindrical shape, the tibia, or shin bone, we shall have demonstration of the correspondence between the shape of the bone and the force which it has to sustain.

If we consider the direction of the force in walking, running, or leaping, and in all the powerful exertions where the weight of the body is thrown forwards on the ball of the great toe, it must appear that the pressure against the shin bone is chiefly on the anterior part: and there is no doubt that if the tibia were a perfect cylinder, it would be subject to fracture even from the mere force of the body itself being thrown upon it. But if the column be stronger in proportion as the material is distant from the centre, we readily perceive how an anterior spine, or ridge, should be thrown out: and if we attend to the internal structure of that spine, we shall find that it is much denser and stronger than the rest of the bone. We cannot, here, deem either the form or the density of this ridge, a thing of accident; since it so perfectly corresponds with the experiment of Du Hamel which we have described, where the dense piece of wood being let into the piece of timber, was found to be a means of resisting transverse fracture. If we proceed, with the knowledge

of these facts, to the examination of the different bones of the skeleton, we shall find that every where the form has a strict relation either to the motion to be performed, or the strain to which the bone is most exposed.

In comparing the true bones with the coverings of the insects, we observed the necessity for the porous structure of the former. If it be necessary that the bone shall be very dense, it will, in that case, no longer be possessed of the power of re-union or re-production when it breaks: it will not re-unite upon being fractured, and if exposed, it will die. Here, then, is an obvious imperfection. The bones of animals cannot, in this manner, be made capable of sustaining great weight, without losing a property which is necessary to their existence—that of restoration on their being injured. And even were the material very much condensed, it does not appear that the phosphate of lime, united as it is with the animal matter, is capable of sustaining any great weight. This accordingly limits the size of animals. It may, perhaps, countenance the belief that animals bear a relation in their size and duration of life to the powers and life of man—that the larger animals have existed in a former condition of the world. We allude only to such animals as have extremities: for with respect to the whale, its huge bulk lies out supported in the water. Some of the great fossil

animals found in the secondary strata are estimated to have been seventy feet in length, and they had extremities. But the thigh and leg did not exceed eight feet in length, while the foot extended to six feet; a proportion, altogether, which implies that the extremities assisted the animal to crawl, rather than that they were capable of bearing its weight, as the extremities of the mammalia. However, we find that in the larger terrestrial animals, the material of the bones is dense, and that their cavities are filled up; the diameters of the bones of the extremities, with their spines and processes, being remarkably large. Nothing can be conceived more clumsy than the bones of the megatherium. Hence it really appears that nature has exhausted her resources with respect to this material; and that living and vascular bone could not be moulded into a form to sustain the bulk and weight of an animal much superior to the elephant, mastodon, and megatherium.*

* The subject may be illustrated in this manner:—"A soft
" stone projecting from a wall, may make a stile strong enough
" to bear a person's weight; but if it were necessary to double the
" length of the stile, the thickness must be more than doubled,
" or a freestone substituted; and were it necessary to make this
" freestone project twice as far from the wall, it would not
" be strong enough to bear a proportioned increase of weight,
" even if it were doubled in thickness: granite must be placed
" in its stead; and even the granite would not be capable of sus-
" taining four times the weight which the soft stone bore in the

With regard to the articulation of the bones, we cannot mistake the reason of the surfaces of contact being enlarged. Now the advantage which is obtained from this expansion of the ends of the bones, is gained without the motion of the joint being impeded. In machinery it is found that, if the pressure be the same, the extension of the surfaces in contact does not increase the friction. If, for example, a stone or a piece of timber, of the shape of a book or a brick, be laid upon a flat surface, it may be drawn across it with equal facility, whether it rests upon its edge or upon its side. The friction of the bones, which enter into the structure of the knee joint, is not increased by their greater diameter: while obvious advantages are gained by their additional breadth; the ligaments which knit these bones give more strength than they otherwise would, and the tendons which run over them, being removed to a distance from the centre, have more power.

“ first instance. In the same way the stones which form an arch, of a large span, must be of the hardest granite, or their own weight will crush them. The same principle is applicable to the bones of animals. The material of bone is too soft to admit an indefinite increase of weight; and it is another illustration of what was before stated, that there is a relation established through all nature: that the structure of the very animals which move upon the surface of the earth is proportioned to its magnitude, and the gravitation to its centre.”—
Animal Mechanics.

OF THE MUSCULAR AND ELASTIC FORCES.

The muscular power is contrasted with the elastic, as possessing a living property of motion. We acquiesce in the distinction, since the muscular fibre ceases to have irritability or power in death, while elasticity continues in the dead part. But yet there is a property in the elasticity of the living body which cannot be retained after death. To illustrate this, we shall take the instance of the elasticity in the catgut string of a harp. Suppose that the string is screwed tight, so as to vibrate in a given time, and to sound the note correctly; if that string be struck rudely, it is put out of tune; that is, it is stretched and somewhat relaxed, and no longer vibrates in time. This does not take place in the living fibre; for here there is a property of restoration. If we see the tuner screwing up the harp string, and with difficulty, and after repeated attempts, bringing it to its due tension,—trying it with the tuning fork, and with his utmost acquired skill restoring it to its former elasticity, we have a demonstration of how much life is performing in the fibres of the animal frame, after every effort or exertion; and the more powerful the mechanical parts of the

body are, the more carefully is the proper tension of the tendons, ligaments, and heart-cords preserved.

Or we may take the example of a steel spring. A piece of steel, heated to a white heat, and plunged into cold water, acquires certain properties; and if heated again to 500° of Fahrenheit, it is very elastic; possessing what is called a "spring temper," so that it will recoil and vibrate. But if this spring be bent in a degree too much, it will lose part of its elasticity. Should the parts of the living body, on the other hand, be thus used, they have a power of restoration which the steel has not.

If a piece of fine mechanism be made perfect by the workman, it may be laid by and preserved: but it is very different with the animal body. The mechanical properties of the living frame, like the endowments of the mind, must not lie idle, or they will suffer deterioration. If, by some misfortune, a limb be put out of use, not only is the power of the muscles rapidly diminished, which every one will acknowledge, but the property of resistance is destroyed; and bones, and tendons, and ligaments quickly degenerate.*

* This subject is illustrated in the Essay on Animal Mechanics, Part II.

On the Position of the Head of Animals and its Relation to the Spine: in Illustration of the Statement made in the body of the Work, that ALL PARTS OF THE SKELETON CORRESPOND WITH EACH OTHER, AND THAT THE VARIATIONS IN THEIR FORM DEPEND SOLELY ON THE FUNCTIONS.

IN the text, in speaking of the upper or anterior extremity, it has been shown that the changes which we see in the forms of different animals are referable to one principle—the adaptation of the parts to their proper uses. We may, in some measure, consider the head in animals as performing the office of hands: and if we take it in this view, we shall see how far it holds true that the centre of the skeleton remains permanent in its form, compared with the variations in the extreme parts. It has been stated as the opinion of some naturalists, that the varieties in the conformation of the skeleton are to be accounted for by a law which preserves the central parts permanent, whilst the extremities are incident to change. I shall controvert that opinion, and show that the spine and head, whilst they retain their offices of protecting the brain and spinal marrow, and are permanent in regard to

them, vary in their processes or shapes, and in their relations. Pursuing this idea, we shall be able to account for the characteristic forms of the larger quadrupeds.

The principle, then, which will guide us here, as it will, indeed, in a more universal survey of animal nature, is, that the organization varies with the condition or the circumstances in which the animals are placed—that they may feed and multiply. If we take into consideration any of the great functions on which life depends, we shall perceive that the apparatus, or the mode of action of the parts is altered and adapted to every changing circumstance. Digestion, for example, is the same in all animals; but there is an interesting variety in the organization: and the stomach will vary in its form and in the number of its cavities, according to the food received, in the quadruped, or bird, or fish, or insect—a variation not depending upon the size or form of the animal, but adapted purely to the conversion of its particular food into nourishment. We shall find the gizzard in a fish or in an insect, as perfect as in the fowl. So the decarbonization of the blood is the same process in all living animals: but the mode in which the respiration is performed varies according to circumstances; and the apparatus is especially modified and adjusted to the atmosphere or to the water.

But although the organs subservient to the grand functions,—the heart and blood vessels, the lungs, the stomach, be variously adapted to the different classes of animals, they change much less than the parts by which animals are enabled to pursue their prey or obtain their food. Their extremities, by which they walk, or run, or creep, or cling, must vary infinitely. And so their teeth and horns and the position of their head and the strength of their neck exhibit nearly as much variety as their proper extremities; because they likewise must be adapted to their different modes of obtaining food, or of combating their enemies. Let us then, in pursuing this principle, observe the meaning of the forms of the more remarkably shaped animals.



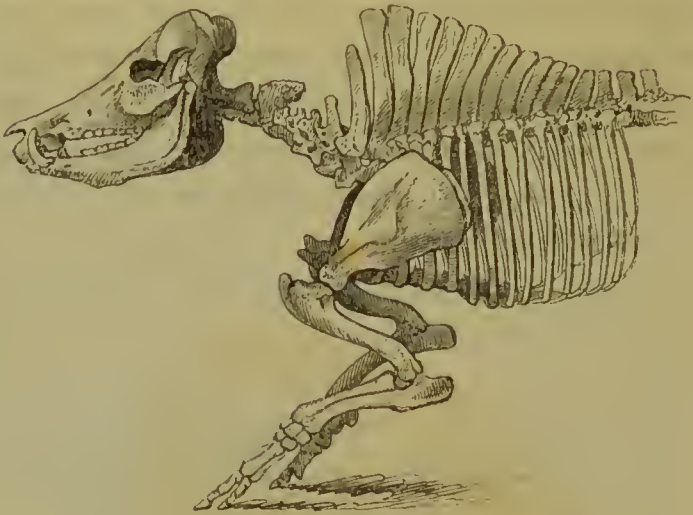
When we look upon the boar's head,* we

* This is a sketch of the dried head of the *Sus Ethiopicus*

comprehend something of his habits ; and see what must be the direction of his strength. He feeds by digging up roots, and the instruments by which he does this, are also those of his defence. The position of the tusk defends the eye in rushing through the underwood ; and the formation of the skull and of the spine and the mass of muscle in the neck, all show the intention that he shall drive onward with his whole weight and strength, so that he may rend with his tusks. Accordingly, we see that the back part of the skull rises in remarkable spines or ridges for the attachment of muscles, and that corresponding with these, the spinous processes of the vertebræ of the neck and back are of extraordinary length and strength. These processes distinctly indicate the power of the muscles which pass from the neck to the head. We now understand the reason of the shortness and inflexibility of the neck : because the power of the shoulders is directed to the head, and, we

with part of the skull exposed. The tusks show what a formidable animal it has been. That which rises out of the upper jaw is of great size, and we must admire the manner in which the tusk of the lower jaw closes upon that of the upper one so as to strengthen it near its root. The great size and sharpness of these tusks illustrate what is offered in the text— that the main strength of the animal must be directed towards them. The rising of the back of the head will be seen to correspond with the great height and strength of the spinous processes of the back exhibited in the next figure, of the wild boar of Germany.

may say, to these large tusks. An elongated and flexible neck would have rendered these provisions useless. The characteristic form of the wild boar, then, consists in the height of the back, the shortness and thickness of the neck, the wedge shape of the head, the projection of the tusk, and the shortness of the fore legs, which must always be in proportion to the neck.



Thus we perceive that the skull, unaffected in its office for containing and protecting the brain, is yet subject to variations in its form and place in reference to its other functions; because it must be adapted, just as the extremities are, to the animal's mode of life. In the same manner, we see that the spine is permanent in its office as a tube to protect the spinal marrow, but that it

varies in its processes and articulations as they bear a reference to the skull: and that although this be the very central part of all, it varies in due degree, and is accommodated to the whole skeleton.

What a complete contrast, then, there is between this animal and any of the feline tribe—a contrast of form and motion at once referrible to their spine. In the tiger or leopard, we see the perfect flexibility of the body, and a motion of the spine, almost vermicular, corresponding with the teeth and jaws and the free motion of the paws.



The peculiarity of form in the elephant has

been happily illustrated by the celebrated Cuvier: and the principle may be pursued in a manner interesting both to the Naturalist and Geologist.

We may feel in ourselves a projection of the spine between the shoulders which marks the process of the "*vertebra prominens*." When we stoop forward, as in reading a book which lies upon the table, we may feel a ligament extending from this process to the back of the head. It suspends the head and relieves the muscles. But as, for the most part, man carries his head balanced upon the extremity of the spine, or can vary its relation under fatigue, that suspensory ligament is not to be compared in strength with the corresponding part in quadrupeds; where from the horizontal position of the spine, the head always hangs: and there would be a great waste of muscular exertion were there not the interposition of this elastic ligament, and were it not of proportionate power.* It is long and strong in the horse; and the admirable thing is the accurate adjustment of the elasticity of this ligament to the weight and position of the head. The head is balanced by it as on a steel-yard. With this circumstance in our mind, let us observe the peculiar form of the elephant.

1. We begin, again, as in treating of the boar,

* See "On the Muscular and Elastic Forces," p. 278.

by observing the teeth. We find that one of the grinders of the elephant weighs seventeen pounds;* and of these there are four in the skull, besides the rudiments of others. 2. We next observe how admirably these grinding teeth are suited to sustain great pressure and attrition. 3. The jaws must be provided to give deep socketing to such teeth: and they must have space and strength to give lodgement and attachment to muscles sufficient for moving this grinding machine. 4. The animal must have its defence too. Now each of the tusks sometimes weighs as much as one hundred and thirteen pounds: and being projected, they may be considered as if placed at the end of a lever. 5. If this enormous and heavy head had hung on the end of a neck having anything like the proportion, in its length, which we see, for example, in the horse, it would have inordinately increased the pressure on the anterior extremities; and more than four times the expenditure of muscular power would have been necessary to the motion of the head. 6. What has been the resource of nature? There are seven vertebræ of the neck in this animal, the same number that we find in the giraffe; but they are compressed in a very remarkable manner, so as to bring the head close upon the

* The natural tooth weighed seventeen pounds, the fossil tooth sixteen and a-half pounds.

body : and thus the head is, as it were, a part of the body, without the interposition of the



neck. 7. But the animal must feed : and as its head cannot reach the ground, it must possess an instrument like a hand in the proboscis,—to minister to the mouth, to grasp the herbage and lift it to its lips. Thus we perceive that the form of the elephant, as far as regards the peculiar character in the shoulders and head, the closeness of the head to the body, the possession of the proboscis, and the defence of that proboscis by the projecting tusks, is a necessary consequence of the weight of the head, and, indeed, of the great size of the animal.

We may carry the inquiry a little further to

the effect of elucidating a very curious part of natural history. The mastodon is the name of an extinct animal, which must have been nearly of the same size as the elephant. It has received that name from the early familiarity of Naturalists with the teeth; which have upon their surfaces of contact mammillary-shaped projections: and it was supposed, at one time, that they might have belonged to a carnivorous animal. But on a portion of the upper jaw being found with the teeth, it admitted of this course of reasoning. 1. In the upper maxillary bone of all vertebrated animals, there is a hole which transmits a branch of the fifth pair of nerves (see p. 149). This nerve goes to the upper lip. But when, as in the elephant, there is the addition of a great proboscis, since that organ possesses sensibility through this nerve, the nerve will be proportionably large, and the hole, consequently, through which it is transmitted. Hence it follows that when we possess a portion of the bones of the face, with the attached tooth of the mastodon, we can infer, by the greater size of this hole or foramen, that the nerve supplied more than the lips—that the animal had a proboscis, and was a species of elephant.

It has been more lately discovered by our conservator in the College of Surgeons, Mr. Clift, that judging by the teeth, and including in the

survey the extinct as well as the living animals, there was a regular series, from the Asiatic elephant to the mastodon of the Ohio. If we consider that tooth to be the most perfect, which is most capable of resisting attrition, either from the mode of its growth or its structure, we shall begin with the great Asiatic elephant. The grinding tooth of this animal consists of alternate layers of the ivory and enamel, and, from the closeness with which these parts are laid together, of a third portion, called *crusta petrosa*. The tooth of the African elephant is easily distinguished, by the wide interstices between the layers of enamel. On the banks of the Irawadi, the tooth of a new species of mastodon is found, where the mammillary processes are so high, and the interstices are so deep that if a section be made of it, it resembles the tooth of the African elephant, and stands intermediate between that and the mastodon giganteum of North America.

Let us consider this principle in another light, and see how the neck and head are accommodated for feeding, when there is no trunk or proboscis, and when the animal has a short neck. The elk is a strange, uncouth animal, from the setting on of its head. The weight of the horns is enormous : and if the head and horns were extended forwards from the body of the animal on an elongated neck, it would be

preposterous and, in fact, they would overbalance the body. Therefore it is, we must



presume, that the head is so curiously approximated to the trunk. When we observe, in the next place, the want of relation between the length of the fore legs and that of the neck, it becomes an interesting circumstance to find that the animal feeds off the sides of the rocks, and does not browse upon the herbage at its feet. A very remarkable proof of the incapacity of this animal to feed in the common way was afforded by an accident which befell a fine male specimen confined in the Zoological Gardens. To reach the ground on which his food was

unintentionally scattered, he had to extend out his fore legs laterally ; in this position his foot slipped, he dislocated his shoulder, and died of the accident.

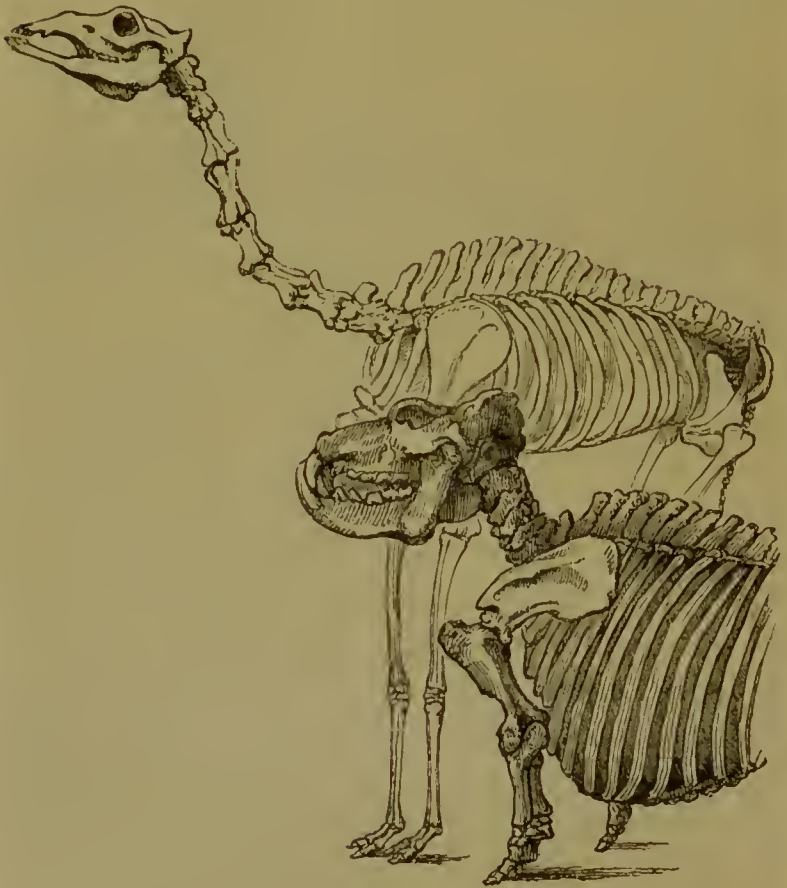
Contrasted with the elk in a most remarkable manner, we have the giraffe ; which feeds upon the branches of lofty trees. The whole constitution and form of this animal is provided to enable it to reach high—the fore legs are long, the neck still longer, the head is remarkably small and light, and the tongue has a power of elongation which no other quadruped possesses. The tongue is, indeed, not inaptly compared with the trunk of the elephant ; he can extend it seventeen inches, and he twists it about, so that it resembles a long black worm ; and it is used with extraordinary dexterity in picking up a straw as well as pulling down a branch. The anatomy of the bones of the giraffe is full of interest too, as showing the accommodation in the structure to the necessities of the animal's condition. And, first, of the head : if we have the skulls of the giraffe and of the camel or horse before us, we are struck with the delicacy of the former : it is cellular, and thin and light as a paper case. Can there be any thing more obvious than that this is provided in consequence of the extraordinary length of the neck, or on the consideration (if we may use the expression) that, if the skull of the giraffe had

been as strong and heavy as that of the horse or camel, it would have preponderated too much at the extremity of such a neck.

There is an accommodation also in the position of the spine. In most quadrupeds the spine lies horizontally. If it had been so placed in the giraffe, the whole weight of the shoulders, neck, and head would have been thrown on the anterior extremities. But from the shortness of the hind legs, and the oblique position of the trunk, the hind legs bear a portion of the weight of the neck and head, parts which, in other creatures, are sustained altogether by the fore legs.* When we look to the ribs, we see another peculiarity that may be accounted for on the same consideration of the length and consequent weight of the neck and head. The chest or thorax rests, of course, upon the anterior extremities: and we shall find that those ribs which bear the pressure are of great comparative strength, while the ribs posterior to these are singularly contrasted with them, by their delicacy and weakness, and by their mobility in breathing. In short, it appears that the fore part of the chest, which, in a manner, intervenes between the neck and the anterior extremities, requires its compages to be particularly firm and strong,

* The ligamentum nuchæ in this animal extends the whole length of the spine, from the os sacrum to the skull.

and that the motions of respiration belong more to the posterior ribs.* Although in this creature



there seems to be a due proportion between the

* We have here a sketch of the skeletons of the hippopotamus and of the camel, as they stood accidentally contrasted. The head of the hippopotamus is of great strength and weight, and it is appended to a short neck ; in the shortness of the legs also we see the correspondence that we have had occasion to remark between the position of the head and the height of the trunk from the ground. The camel is, in every respect, a contrast. It must

legs and the neck, yet he is not suited to browse the grass, but to feed on the high branches of trees. In the attempt to reach the ground with his mouth the limbs appear to be in danger of suffering dislocation. He extends his feet laterally, elevates the scapulæ, draws in the crupper, and stretches the neck, so as to present a very ludicrous figure.

OF THE HORSE'S HEAD.—It is perhaps better to draw our argument from something familiar and constantly before us: let us, then, take it from the form of the horse. It has been affirmed that the sound of neighing in the horse results from two cavities in the head, called the Eustachian cavities, because they communicate with the tubes of that name which lead from the ear to the throat: but this is a very unsatisfactory account of these cavities. We are of opinion that they are connected with this subject, the weight of the head, the power of mastication, and the length of the neck. It is a very remarkable circumstance that a horse, whose “points” are approved of by the jockeys, will

have rapidity and ease of motion; that is secured by the length of the extremities; and according with the extremities, are the length of the neck and the lightness of the head. Here is a skeleton, then, of an animal which is properly terrestrial, accommodated to all the other peculiarities of its organization, and adapted for a rapid and long continued course: the hippopotamus, on the other hand, seeks its safety in the water,—and its uncouth form and weight are suited to that element.

starve in a grass field ; for by breeding and crossing they contrive, in a manner one would almost say artificially, to combine the incidental defects of nature, so as to make the proportions of the animal correspond with their ideas of perfection ; for they have got a notion that a short neck and a small head are excellencies, as diminishing the weight upon the fore feet. They observe that the splints, corns, sand-cracks, whitters, inflammations, and other diseases of the horse's foot, are almost exclusively found in the anterior extremity, and they attribute these to the weight of the head and neck in conjunction with the artificial condition of the horse. Were it the shoeing and the hard roads, the effect would be equally perceptible on the hind feet. Such considerations tend to show the importance of the peculiarity now to be pointed out in the horse's skull.

On looking to the horse's head in profile, we see that its peculiar form, and especially the great depth of jaws, posteriorly, is a necessary consequence of the length of the grinding teeth. We have already noticed the magnitude and weight of the elephant's head, corresponding with the enormous teeth, formed for attrition. If we apply the same rule to the head of the horse, we shall see how curiously it accounts for the peculiar shape of its skull. Like the elephant, it is graminivorous ; and the structure of

the teeth evinces how well they are calculated to masticate without wasting. To enable them to bear great pressure they are socketted deeply in the jaw ; and as the strength of the muscles is not provided merely for closing the jaws, as in the carnivorous animals, but for grinding or drawing the jaw laterally, there is extraordinary space given for the lodgement of the muscle called masseter, which has the double action of closing the teeth and of drawing the lower jaw across the upper, as in mastication. Here then, we have the reason for that large square portion of the jaw under the ear, which peculiarly distinguishes the horse's head.

The maxillary and nasal cavities are very large, but the space which they occupy does not suffice to correspond with the remarkable depth of the lower jaw. In fact, the larynx and pharynx, the contained parts, cannot fill up the whole depth of the head here, so that above these tubes there is a great space, neither required for the lodgement of the brain, nor for the bony cavities of the nose, nor for the pharynx, nor the trachea, but solely resulting from the great size of the jaws. Had this been occupied by solid bone, it would have added materially to the weight of the head ; the space, therefore, betwixt the upper part of the spine, the jaw, and the base of the skull, is filled up by two great membranous cells, which have a communication with

the cavities of the nose. On the whole, then, we may consider these great cells in the horse's head as permitting the enlargement of the jaw bone at its back part, so as to afford a deep socketting for the grinding teeth, and to give a sufficient lodgement for the powerful muscles employed in mastication, without very considerably increasing the solid material of the head. Advantage is here taken of the admission of air to increase the volume and strength of the parts, as in birds, without adding to the weight.

We have said that jockeys observe the effect of a large and heavy head in a horse; we now perceive that if the horse's skull had been formed without this provision, the head must have greatly exceeded in weight, and in the running horse especially, this would have been a positive defect; for in running, the horse would not have been properly balanced upon its extremities, and the weight upon the fore-feet would have been so much increased as to have rendered him still more liable to those diseases of the foot which artificial condition subjects it to.

This provision, by which the head of the horse is made lighter, has a parallel in the head of the spermaceti whale. The spermaceti whale is a species of the physeter or cachelot whale, which has a very large head, and is remarkable for having teeth; the common whale having only whale bone in its mouth. It is probable that the length of the head thus loaded as it is, throws

the lungs too far behind the centre of gravity, to permit the head to be buoyant; therefore, the large cavities about the head, (twelve feet long, and four feet deep) are filled with a material lighter than the water, and thus the equilibrium is maintained.

Although the changes in the shape of the skulls of animals are principally forwards, yet the slighter deviations in the back part may indicate much, if minutely scanned. For example, a portion of a skull was found, among other interesting specimens of fossil bones, in the caves of the limestone rocks, near Plymouth. It consisted merely of the condyles or articulating processes of the skull which join it to the vertebræ of the neck, and a portion of the occipital and temporal bones. Yet from these it could be ascertained that the fragment belonged to an hyæna: although its proportions were double those of the corresponding parts of the largest of the recent species. First, the high spine showed the strength of the neck; secondly, the depth and extent of the fossa or hollow for the lodgement of the temporal muscle proved that there was a remarkable mass, and consequent strength of muscle for closing the jaws; thirdly, it belonged neither to the bear nor to the tiger, which was shown by the extraordinary thickness and density of the whole bone. In this last respect, the portion of bone corresponded with

no animal but the hyæna; for the skull of the hyæna participates in the strength which is so remarkable in its teeth; these being capable of breaking the strongest bones.*

On this subject, Dr. Buckland has given an example of deduction, founded on the structure of the teeth of the hyæna, not inferior to the best specimen of Cuvier's reasoning on the fossil bones. In lecturing on the comparative anatomy of the skeleton, I put the subject in this light:—"We have seen that all nature is full of life; and where food is to be obtained, there are animals in structure suited to reach it. Suppose that the horse is run down by the wolf, and fed upon by the lesser carnivorous animals and birds of prey: in these large cylindrical bones which are left, there is abundance of nutriment, and yet these animals cannot get at it. Turn your attention, then, to the skull of the hyæna. It has a clumsiness and weight, in contrast with that of the dog, or the wolf, or the bear: and observing the teeth, you see them conical—which is the very form of strength, and they are, indeed, as if case-hardened, compared with those of other animals. Proportioned to the power of resistance of the teeth are the

* This specimen is in the Museum of the College of Surgeons, and is beautifully drawn in Mr. Clift's paper in the Philosophical Transactions.

size and density of the jaws. This hollow for the lodgement of the temporal muscle, which closes the jaws, and this prominence of the zygomatic arch, which gives attachment to another muscle of the same class, produce the extraordinary breadth of face of this very ugly animal ; and corresponding with the strength of its teeth, jaws, and muscles, you see that the whole skull is thicker and denser in its texture, as if to show, by the supporting frame-work, the strength of the engine ; an engine capable of breaking these powerful cylindrical bones of larger animals, and of disclosing a rich repast in the marrow.”

In the earlier part of the volume, we have noticed the most remarkable peculiarities of the skeletons of birds ; and we may take this opportunity of observing the relation between the form of the bird and some of the principal functions. Putting digestion and respiration for the present, out of the question, the continuation of the species is the next in importance. Now a bird, to be buoyant and capable of flying, could not have been viviparous. If we have seen that a full stomach impeded the flight of a carnivorous bird, it is evident that it could not have carried its young within it. Is it not curiously provided, then, that the bird shall produce its offspring by a succession of small eggs, which shall accumulate in the nest, instead of

growing in the body? In short, it requires no argument to prove that the hollow bones of the skeleton, the extension of the breast-bone, the air-cells, the quill-feathers, the bill, and the laying of eggs, are all in necessary relation to each other.

Since we have spoken of the relation of the form of the skeleton to the continuation of the species, in the bird, we may for the same object revert to the quadrupeds. In all the mammalia, there is nothing more extraordinary than the deviation in the skeleton of the kangaroo from the general form. Joined to this, there is a remarkable peculiarity in the manner in which this animal produces its young. Instead of remaining within the mother for the usual period of gestation, the young, by some peculiar mode not perfectly understood, are excluded from within the belly, and are found attached to the teats; where they hang by the mouth, covered by an exterior pouch, formed of the skin, until from minute and shapeless things, they are matured to the degree in which the young of other animals are usually brought forth.

Now we think that the upright position of this animal (for it is the only creature except man which rests in the perpendicular), and the disproportioned magnitude of the lower part of its body, are the reasons of the peculiarity in its mode of gestation. Without entering far into

this subject, we may observe that there must be an accurate correspondence between the form of the young offspring and the bones of the mother through which it must be expelled. The head and anterior part of the young animal must be large: but in the kangaroo, the anterior part bears no proportion to the magnitude of the parts behind. Again, the bones called pelvis are necessarily formed to sustain the viscera, if the animal be provided for the perpendicular position; and this is the case with the kangaroo. Nature has, therefore, accomplished the production of the young safely and by the simplest means,—that of anticipating the period of the separation of the young animal, and providing for its growth exteriorly, after it has passed through the circle of bones called the pelvis. For these reasons we conclude that there is a relation between the mode of producing the offspring and the form of the skeleton.

I hope that I have gone far enough to prove that where there is uniformity in the shape of any part of the skeleton, it depends on the permanence of the function of the organ to which it stands related. The head and spine are, in certain respects, permanent in their forms; because the brain and spinal marrow vary only in size: but as far as regards their application as instruments for obtaining food, for attack, or defence, they are very curiously changed in

their processes and articulations, and suited to the varying uses of the parts; and we may observe that there is no change in any part of the body—whether in the spine, or the occiput, or the jaws, or the teeth, or the pelvis, or the extremities—without a corresponding adaptation extending through the whole skeleton.

IMAGINARY ANIMALS.

ARCHDEACON PALEY has said, “no doubt we can imagine a greater variety of animals than do actually exist.” But what is the fact? If we look to the fabled animals of antiquity, not one of them could have existed; and it may serve to show the imperfection of man’s ingenuity compared with nature, and at the same time demonstrate the perfection of the system of the animal body, if for a moment, we survey these imaginary animals and enquire whether they could have fed, or breathed, or moved, or flown.

What, in fact, are these monstrous fancies, but the incongruous union of parts, which, patched together without order or system, could not have belonged to a living creature. Nor is there any real invention here; as when the head of a lion is joined to the belly of a goat, or the head of a woman to the body of a bird, or to the tail of a serpent. Of the Centaurs, the Satyrs of the

Indian mountains, the Sphynxes of Egypt, the Griffins among the one-eyed nations, not one could have stood, run, or flown. It may be alleged that these figures are but allusive representations—mystical types of some country or element; but it is sufficient to our argument, that they are the only imaginary animals, and are acquiesced in by the classical reader as having a fanciful existence.

Let us take for our example the Centaur. When we look to the representation in the antique marble, the merit of the sculptor is shown in the attempt to reconcile our fancy to the unnatural union of the members. The expansion of the nostrils and the coltish wildness of the expression are indicative of the artist's design, to join the human form to that of the horse. But this could never succeed with him who has been narrowly inspecting the proportions of the horse. If he see in a horse a fore-quarter too heavy, or a long neck and a large head, and observe that these are incompatible with wind and speed, and safe going, and conclude that such an animal must founder in the feet, what would he say to the Centaur, where an additional body, head and shoulders, are made to rest upon the fore-feet? The subject is classical, at least Galen takes it up, and wonders if Pindar could believe in the Centaurs. "For," says he, "if such an animal were to have existence, is

ought to have two mouths; one to correspond with the stomach of man, and the other to masticate for the stomach of the horse. If it could run upon the plain, it could not climb the hill, or make its way in rocky places. Though possessed of human faculties, it could not build for itself an habitation, or navigate ships and man the sails;" and more particular still in his objections, he adds, "that it could neither sit like the tailor, nor make shoes like the cobbler."

But to return to our own argument, we may observe how nature manages to rear a superior incumbent weight upon the fore-quarters, by examining the structure of the skeleton of a Giraffe. There, we see how the pressure is taken off the fore-quarters, by the obliquity of the spine, and the shortness of the hind-legs. However beautiful as works of art, the figures of the Centaurs upon antique gems may be, they are yet monsters,—their construction, a joining of inconsistent parts together.

As a trial of skill, there are few designs more difficult to execute than the representation of a Fawn or Satyr; because the artist has incongruities to reconcile—the human form and face, to the limbs of a brute. If we have attended to the size and shape of the human extremities, we see the impossibility of rearing the human trunk upon the legs of a goat—the bones are too small, the masses of muscle are displaced. The

painter and the sculptor do not think of this, when they represent their Fawns dancing and piping ; but an instant's thought of the position of the bones, and the action of the muscles must show that they are incapable of such activity. Were such forms actually in being, they must creep weakly on the ground.

And so of the Griffin : the eagle's wings could never raise the body of a lion. To raise a creature on the wing, there must be a mass of muscle proportioned to the extended wing—and a surface of bony texture for the lodgement and attachment of these muscles for flight. The bones of a lion are dense and heavy, and proportioned to its muscular strength : and to extend the skeleton, composed of such bones, would never form a creature buoyant in the air. By which we see that, were the external forms consistent, there is wanting that internal conformation necessary to the real existence of the animal. The lion's tail, again, would be a very useless appendage, compared with the fine rudder which enables the eagle to direct his swoop.

These instances might be multiplied ; but we venture to say that every animal form, not actually existing in nature, but the invention of the poet, would be deficient in some balance of the exterior members, or some relation of parts necessary for motion ; and were the exterior and moving parts duly balanced, some internal organ would be found not conformable, or displaced—

too much developed, or too much compressed. In short, man's imagination is more limited than we, at first, may have believed; our inventions are the incongruous union of things seen in nature. It is, indeed, far beyond our power to accomplish what Paley has supposed possible; for he has said, "that multitudes of conformations, both of vegetables and animals, may be conceived capable of existence and succession, which yet do not exist." This manner of viewing the subject serves only to confirm us in the belief of the perfection of that natural system of parts which admits the changes necessary to the walking, running, flying, and swimming, of such an infinite variety of creatures, and at the same time accommodates the internal functions, which minister to life, so that they are consistent with every variety of condition to which the animal may be destined.



A COMPARISON OF THE EYE WITH THE HAND.

IF we are in search of an object which shall excite the highest interest, and at the same time afford proofs of design, we naturally turn to the eye as the most delicate of all the organs of the body: and this suits our present purpose the better, that we have to show how much of the sense of vision depends on the hand, and how strict the analogy is between these two organs.

From the time of Sir Henry Wotton to the latest writer on light, the eye has been a subject of admiration and eulogy. But I have ventured, on a former occasion,* to say, that this admiration is misplaced, while it is given to the ball of the eye and the optic nerve exclusively; since the high endowments of this organ belong to the exercise of the whole eye, to its exterior apparatus, as much as to its humours and the proper nerve of vision. It is to the muscular apparatus, and to the conclusions which we are enabled to draw from the consciousness of muscular effort,

* See Philosophical Transactions.

that we owe that sense by which we become familiar with the form, magnitude, and relations of objects. One might as well imagine that he understood the effect and uses of a theodolite by estimating the optical powers of the glasses, without looking to the quadrant, level, or plumb-line, as suppose that he had learnt the whole powers of the eye by confining his study to the naked ball.

We must begin our observations by a minute attention to the structure and sensibility of the retina. The retina is the internal coat of the eye; it consists of a delicate, pulpy, nervous matter, which is contained between two membranes of extreme fineness, and these membranes both support it and give to its surfaces a smoothness mathematically correct. The matter of the nerve, as well as these supporting membranes, are perfectly transparent during life. In the axis of the eye, there is a small portion which remains transparent, when the rest of the membrane becomes opaque, and which has been mistaken for a foramen,* or hole in the retina. It is surprising, that with all the industry which has been employed to demonstrate the structure of the eye, it is only in the present day that a most essential part of the retina has been discovered—the membrane of Mr. Jacob. From

* It is this part which is called the foramen of Soemmerring.

observing the phenomena of vision, and especially the extreme minuteness of the image cast upon the retina, I had conceived that the whole nerve was not the seat of vision, but only one or other of its surfaces. This could not be well illustrated until the exterior membrane of the retina was demonstrated. But now we see that this membrane, when floated in water and under a magnifying glass, is of extreme tenuity, and its smooth surface is well calculated to correspond with the exterior surface of that layer of nervous matter which is the seat of the sense.

The term retina would imply that the nerve constitutes a network : and the expressions of some of our first modern authorities would induce us to believe that they view it in this light, as corresponding with their hypothesis. But there is no fibrous texture in the matter of the nerve ; although, when the retina is floated and torn with the point of a needle, the innermost of the membranes which support the nerve, the *tunica vasculosa retinae*, presents something of this appearance.

Vision is not excited by light unless the rays penetrate through the transparent retina and reach the exterior surface from within.

It is well known, that if we press upon the eye-ball with a key or the end of a pencil-case, zones of light are excited. The perception of that light is, as if the rays came in a direction

opposite to the pressure. We may say that, in this case, the effect of the pressure is assimilated to that of light; and as light can strike the part of the nerve which is pressed, only by coming in an opposite direction, the zones of light produced by the mechanical impulse appear in the usual direction of rays impinging upon this part: and consequently, they give the impression of their source being in the opposite quarter. Let us contrast this phenomenon with the following experiment. Let the eyelids be closed, and covered with a piece of black cloth or paper which has a small hole in it; place this hole, not opposite to the pupil, but to the white of the eye: then direct a beam of light upon the whole, and this light will be seen in its true direction. Why is there, in these two cases, a difference in the apparent place from which the light is derived? Is it not that the rays directed upon the eyeball, after striking upon the retina, pierce through it and through the humours of the eye, and impinge upon the retina on the opposite side. This explains why the light excited in the eye shall appear to come from different quarters: but it does not explain why there should not be a double impression—why the beam of light should not influence the retina while penetrating it in the first instance, that is, in passing through it from without inwards, as well as when it has penetrated the humours

and strikes upon the opposite part of the retina from within outwards.

Another fact, which has surprised philosophers, is the insensibility of the optic nerve itself to light. If it be so contrived that the strongest beam of light shall fall upon the end of the nerve in the bottom of the eye, where it begins to expand into the delicate retina, no sensation of light will be produced. This ought not to surprise us, if I am correct in my statement that the gross matter of the nerve is not the organ of vision, but the exterior surface of it only. In the extremity of the optic nerve there is, of course, no posterior surface; and, indeed, nothing can better prove the distinct office of the nerve itself as contrasted with the expanded retina, than this circumstance,—that when the strongest ray of light strikes into the nerve, the impression is not received. It seems to imply, that the capacity of receiving the impression, and of conveying it to the sensorium are two distinct functions.

Is not this opinion more consistent with the phenomena than what is expressed by one of our first philosophers,—that the nerve, at its extremity towards the eye, is insensible, and forms what has been called the *punctum cæcum*, because it is not yet divided into those almost infinitely minute fibres, which are fine enough to be thrown into tremors by the rays of light.

Independently of this punctum cœcum, we have to observe that the whole surface of the retina is not equally sensible to light. There is a small spot, opposite to the pupil and in the axis of the eye, which is more peculiarly sensible to visual impressions. An attempt has been made to ascertain the diameter of this spot; and it is said, that a ray at an angle of five degrees from the optic axis, strikes exterior to this sensible part. But we shall, on the contrary, see reason to conclude, that the sensible spot is not limited to an exact circle, that it is not regularly defined, and that the sensibility, in fact, increases to the very centre.

Some have denied the existence of this extreme sensibility in the centre of the retina, attributing the distinctness of vision to the circumstance of the light being made to converge, through the influence of the humours, more correctly to this point. I shall, therefore, show how impossible vision would be, were it not that the sensibility of the retina increases gradually, from its utmost circumference, to the point which forms the axis of the eye.

We see objects by reflected light, at the very instant that direct light enters the eye. As the impression by the direct light is many times stronger than the reflected rays from the object, the vision of the object would be destroyed by the contrast, were there not this admirable pro-

vision in the retina, that the direct light shall fall upon a part less sensible, the reflected light upon a part more sensible. If, in full day, and in the open field, the eye be directed southward, the rays from the sun enter the eye at the time that we are looking to certain objects: and it is perfectly clear, that if the sun's rays struck a part of the retina as sensible as the spot in the centre or axis, they would extinguish all secondary impressions: the glare would be painfully powerful, as when we look directly to the sun. If a momentary glance towards the sun produce a sensation so acute that we see nothing for some time after, would not the same happen were the retina equally sensible in all its surface? A similar effect takes place in a chamber lighted with candles; we do not see the person immediately on the other side of the candle: for there the direct light interferes with the reflected light, effacing the slighter impression of the latter.

We perceive, therefore, that if the retina were equally sensible over its whole surface, we could not see. Let us, then, observe how we do actually see, and how the organ is exercised. There is a continual desire of exercising the sensible spot, the proper seat of vision. When an impression is made upon the retina, in that unsatisfactory degree which is the effect of its striking any part but the centre, there is an effort made to direct the axis towards it, or, in

other words, to receive the rays from it upon the more sensible centre. It is this sensibility, therefore, conjoined with the action of the muscles of the eye-ball, which produces the constant searching motion of the eye ; so that, in effect, from the lesser sensibility of the retina generally, arises the necessity for this exercise of the organ ; and to this may be attributed its high perfections.

This faculty of searching for the object is slowly acquired in the child ; and, in truth, the motions of the eye are made perfect, like those of the hand, by slow degrees. In both organs there is a compound operation :—the impression on the nerve of sense is accompanied with an effort of the will, to accommodate the muscular action to it. It is no contradiction to this, that the faculty of vision is made perfect in the young of some animals from the beginning ; no more than that the instinct of the duck, when it runs to the water the moment that the shell is broken, should contradict the fact that the child learns to stand and walk after a thousand repeated efforts.

Let us now see how essential this searching motion of the eye is to vision. On coming into a room, we see the whole side of it at once—the mirror, the pictures, the cornice, the chairs ; but we are deceived : being unconscious of the motions of the eye, and that each object is

rapidly, but successively, presented to it. It is easy to show, that if the eye were steady, vision would be quickly lost: that all these objects, which are distinct and brilliant, are so from the motion of the eye: that they would disappear if it were otherwise. For example, let us fix the eye on one point, a thing difficult to do, owing to the very disposition to motion in the eye: but by repeated attempts we may at length acquire the power of fixing the eye to a point. When we have done so, we shall find, that the whole scene becomes more and more obscure, and finally vanishes. Let us fix the eye on the corner of the frame of the principal picture in the room. At first, every thing around it is distinct; in a very little time, however, the impression becomes weaker, objects appear dim, and then the eye has an almost uncontrollable desire to wander; if this be resisted, the impressions of the figures in the picture first fade: for a time, we see the gilded frame: but this also becomes dim. When we have thus far ascertained the fact, if we change the direction of the eye but ever so little, at once the whole scene will be again perfect before us.

These phenomena are consequent upon the retina being subject to exhaustion. When a coloured ray of light impinges continuously on the same part of the retina, it becomes less sensible to it, but more sensible to a ray of the

opposite colour. When the eye is fixed upon a point, the lights, shades and colours of objects continuing to strike upon the same relative parts of the retina, the nerve is exhausted : but when the eye shifts, there is a new exercise of the nerve : the part of the retina that was opposed to the lights, is now opposed to the shades, and what was opposed to the different colours is now opposed to other colours, and the variation in the exciting cause produces a renewed sensation. From this it appears, how essential the incessant searching motion of the eye is to the continued exercise of the organ.

Before dismissing this subject, we may give another instance. If we are looking upon an extensive prospect, and have the eye caught by an object at a distance, or when, in expectation of a friend, we see a figure advancing on the distant road, and we endeavour to scrutinize the object, fixing the eye intently upon it, it disappears ; in our disappointment we rub the eyes, cast them about, look again, and once more we see the object. The reason of this is very obvious : the retina is exhausted, but becomes recruited by looking on the other objects of different shades and colours. The sportsman on the moor or the hill side, feels this a hundred times when he marks down his covey, fixing his eye and travelling towards the spot.

Here we may interrupt our inquiry to observe how inconsistent these phenomena are with the favourite hypothesis—that light produces vision by exciting vibration in the fibres of the nerve. By all the laws of motion from which this hypothesis is borrowed, we know that if a body be set in motion, it is easily kept in motion; and that if a chord vibrate, that vibration will be kept up by a motion in the same time. It appears to me natural to suppose, that if these fibres of the nerve (which, be it remembered, are also imaginary) were moved like the chords of a musical instrument, they would be most easily continued in motion by undulations in the same time: that if the red ray oscillated or vibrated in a certain proportion of time, it would keep the fibres of the nerve in action more easily, than a green ray, which vibrates in a different time; and if the colour of a ray depended upon the peculiar undulation or vibration, before the green ray could produce a motion corresponding with itself, it must encounter a certain opposition, in interrupting the motion already begun.*

* “ Although any kind of impulse or motions regulated by any
“ law may be transferred from molecule to molecule in an elastic
“ medium, yet in the theory of light it is supposed that only such
“ primary impulses, as recur according to regular periodical laws,
“ at equal intervals of time and repeated many times in succession,
“ can affect our organs with the sensation of light. To put in
“ motion the molecules of the nerves of our retina with sufficient

Reverting to the sensible spot in the retina, it does not appear that we are authorised to term it a spot. The same law governs vision when we look to a fine point of a needle, or to an object in an extensive landscape. We look to the point of a pen, and we can rest the attention on the point upon the one side of the slit, to the exclusion of the other, just as we can select and intently survey a house or a tree. If the sensible spot were regularly

“ efficacy, it is necessary that the almost infinitely minute impulse
 “ of the adjacent ethereal molecules should be often and regularly
 “ repeated, so as to multiply and concentrate their effect. Thus,
 “ as a great pendulum may be set in swing by a very minute
 “ force, often applied at intervals exactly equal to its time of
 “ oscillation, or as one elastic body can be set in vibration, by the
 “ vibration of another at a distance propagated through the air,
 “ if in exact unison, even so we may conceive the gross fibres of
 “ the nerves of the retina to be thrown into motion by the conti-
 “ nual repetition of the ethereal pulses : and such only will be thus
 “ agitated, as from their size, shape, or elasticity, are susceptible
 “ of vibrating in times exactly equal to those at which the impulses
 “ are repeated. Thus it is easy to conceive how the limits of visible
 “ colour may be established : for if there be no nervous fibres in
 “ unison with vibrations more or less frequent than certain limits,
 “ such vibrations, though they reach the retina, will produce no
 “ sensation. Thus, too, a single impulse, or an irregularly re-
 “ peated one, produces no light. And thus also may the vibrations
 “ excited in the retina continue a sensible time after the exciting
 “ cause has ceased, prolonging the sensation of light (especially
 “ if a vivid one) for an instant in the eye in the manner des-
 “ cribed.”—Sir J. F. W. Herschel, *Art. Light. Enc. Met.*

Now it does appear to me that this reasoning is inconsistent with the phenomena above noticed.

defined, it must be very small: and were it, indeed, so defined, we should be sensible of it; which we are not. The law, therefore, seems to be, at all times, that the nearer to the centre of the eye, the greater is the sensibility to impression; and this holds whether we are looking abroad on the country, or are microscopically intent upon objects very minute.

When men deny the fine muscular adaptation of the eye to the sensation on the retina, how do they account for the obvious fact—that the eye-ball does move in such just degrees? how is the one eye adjusted to the other with such marvellous precision? and how do the eyes move together in pursuit of an object, never failing to accompany it correctly, be it the flight of a bird, or the course of a tennis-ball, or even of a bomb-shell? Is it not an irresistible conclusion—that if we so follow an object, adjusting the muscles of the eye so as to present the axis of vision successively to it, as it changes place, we must be sensible of these motions? for how can we direct the muscles unless we be sensible to their action? The question then comes, to be—whether being sensible to the condition of the muscles, and being capable of directing them with this extraordinary minuteness, this action of the muscles does not enter into our computation of the place of an object? But is not this exactly the same question recurring as when we asked—whether

we can direct the hand without knowing where the hand is? Must there not be a feeling or knowledge of the position of the hand, before we can give it direction to an object? And must we not have a conception of the relation of the muscles and of the position of the axis of the eye, before we can alter its direction to fix it upon a new object?

It surprises me to find ingenious men refusing their assent to the opinion, that the operation of the muscles of the eye is necessary to perfect vision, when the gradual acquisition of the power may be seen in observing the awakening sense in the infant. When a bright object is withdrawn from the infant's eye, there is a blank expression in the features; and an excitement when the object is again presented. For a time, the shifting of the object is not attended with the searching action of the eye: but, by and by, the eye follows it and looks around for it, when it is lost. In this gradual acquisition of power in the eye, there is an exact parallel to the acquisition of motion in the hand; and in both instances, we seek to join the experience obtained by means of the muscular motion with the impression on the proper nerve of sense.

Some maintain that our idea of the position of an object is implanted in the mind and independent of experience. We must acknowledge

the possibility of this, had it been so provided. We see the young of some creatures with their vision thus perfect at the moment of their birth. But in these animals, every corresponding faculty is, in the same manner, perfect from the beginning: the dropped foal, or the lamb, rises and follows its mother. We must no more compare the helpless human offspring with the young of these animals than with a fly, the existence of which is limited to an hour at noon,—which breaking from its confinement, knows its mate and deposits its eggs on the appropriate tree—the willow or the thorn, and dies. But this is foreign to our enquiry; since it is obvious that the human eye has no such original power of vision bestowed upon it, and that it is acquired, as the exercise of the other senses, and the faculties of the mind itself are, by repeated efforts, or experience.

If it be admitted that the ideas which we receive through the eye come by experience, we must allow that the mind must be exercised in the act of comparison, before we can have a conception of any thing being exterior to the eye, or of an object being placed in a particular direction. Authors make the matter complex by conceiving a picture to be drawn at the bottom of the eye, and presenting to us the mind contemplating this inverted picture, and comparing the parts of it. But this leaves

the subject without any explanation at all, and does not show how it is that the mind looks into this camera. The question will be, at least, more simple, if we consider the vision of a point; and ask ourselves how we know the direction in which that point comes to the eye. Suppose it is a star in the heavens, or a beacon, seen by the mariner. Must he not, in order to ascertain the position of the star, find out some other object of comparison, some other star, which shall disclose to him the constellation to which the one that he is examining belongs: or to ascertain the position of the beacon, must he not look to his compass and card, and so trace the direction of the lighthouse in relation to them? This is, in fact, the process that is followed in every thing which we see. A single point is directly in the axis of the eye, but we cannot judge of its position, without turning to some other point, and becoming sensible of the traversing of the eye-ball and the angle to which the eye is moved: or if we do not see another point to compare the first with, we must judge of its place by means of a comparison with the motion of the eye itself. We are sensible that the eye is directed to the right or to the left; and we compare the visible impression on the nerve with the motion, its direction, and its extent.

We find even mathematicians affirming that we judge of the direction of an object by the

ray that falls upon the retina, and the line in which it comes to the eye. But the ray which is here spoken of strikes a mere point of the retina: this point can have no direction; the obliquity of the incidence of the ray can inform us of nothing: rays of all degrees of obliquity are converging to form that point; and do not the same mathematicians give us, in the first lessons of their science, as the definition of a line—that which is drawn through two points at the least? Where are the two points here to indicate the direction of the line,—since the cornea, or the humours of the eye,* are not sensible to the passage of the ray? Or is this an error which has crept in from inaccurate conceptions of the anatomy? Has the idea that the direction of the ray can afford this knowledge, arisen from the notion that the ray passes through the thick and turbid matter of the retina? I would ask for what reason is the “finder” attached to the great telescope? is it not because the larger instrument, from magnifying one object in a high degree, cannot be directed in the heavens—the observer seeing with it nothing but that one object? Accordingly, to remedy this there is mounted on the greater telescope a smaller one exactly parallel, of lesser power, but commanding a wider field;

* See a paper by Mr. Alexander Shaw, who has explained this subject very happily.—Journal of the Royal Institution, 1832.

this "finder" the astronomer directs to the constellation, and moves from star to star until the one which he desires to examine is in the centre of the field: and it is by this means that he adjusts the larger telescope to his object. Is this not a correct illustration of the operation of the eye? Is the eye not imperfectly exercised when it sees but one point: on the other hand, is it not in the full performance of its function when it moves from one object to another, judges of the degree and the direction of that motion, and thus enables us, by comparison, to form our judgment?

It has been stated by a most ingenious philosopher of our time, in opposing these views of the compound nature of the sense of vision, that the forms and relations of objects are known to us by the unassisted operation of the eye-ball itself—by the transmission of the rays through the humours of the eye, and by their effect upon the retina; and he has also affirmed that we should know the position of objects even if the muscles of the eye were paralytic. But I hope that it has been understood, when I give so much importance to the motions of the eye, that I do not neglect the movements of the body, and, more especially, the motions of the hand: that, in truth, the measure of objects which we take through the eye, is in correspondence with the experience which we

have had through the motions of the whole frame ; and that, without such experience, we should have no knowledge of matter, or of position, or of distance, or of form. Were the eye fixed in the head, or paralytic, we should lose a great part of the exercise of the organ, as well as all the appliances which are necessary for its protection : but we should still be capable of comparing the visual impression with the experience of the body. As long as we know the right hand from the left, or must raise our head to see what is above us, or stoop to see a man's foot, there can be no want of materials to form a comparison between the impression on the nerve of sight and the experience of the body.

Against this view of the compound operation of the eye, the matter is thus argued:—if a man receive the impression of a luminous body upon his eye, so that the spectrum shall remain when the eye-lids are shut, and if he be seated upon a stool that turns round, and be whirled round by the hand of a friend, without his own effort, the motion of the spectrum will correspond with his own. No doubt it will : because he is conscious of being turned round : a man cannot sit upon a stool that is turning without an effort to keep his place, without a consciousness of being turned round ; and feeling, at the same time, that the impression is still before his eye, he will see the spectrum before

him, and in that aspect to which he has been revolved.

Were I not conscious that I am right, I should feel it necessary to make an apology for arguing against the opinions of eminent men on this matter ; but I conceive the explanation of this discrepancy to be, that we are very much influenced by the manner in which we approach the examination of such a subject. A man lost in admiration of the properties of light, and of the effect of the humours of the eye as an optical instrument, may be blinded to those inferences, which to me seem so undeniable, accustomed as I have been to compare the properties of the eye with the living endowments of the frame. When instead of looking upon the eye as a mere camera or show-box, with the picture inverted on the bottom, we determine the value of muscular activity ; mark the sensations attending the balancing of the body ; that fine property which we possess of adjusting the muscular frame to its various inclinations ; how it is acquired in the child ; how it is lost in the paralytic and drunkard ; how motion and sensation are combined in the hand ; how, in this way, the hand guides the finest instruments : when we consider how the eye and the hand correspond ; how the motions of the eye, combining with the impression on the retina, become the means of measuring and estimating the place, form, and distance

of objects—the sign in the eye of what is known to the hand : finally, when, by attention to the motions of the eye, we are aware of their extreme minuteness, and how we are sensible to them in the finest degree—the conviction irresistibly follows, that without the power of directing the eye, (a motion holding relation to the action of the whole body) our finest organ of sense, which so largely contributes to the developement of the powers of the mind, would lie unexercised.

THE MOTION OF THE EYE CONSIDERED IN REGARD TO THE EFFECT OF SHADE AND COLOUR IN A PICTURE.

A QUESTION naturally arises whether it be possible, from this part of philosophy, to suggest some principles for the amateur and painter. The ideas and language of the amateur, when he attempts to establish rules for the disposition of colours or shades in a picture, are certainly very vague.

We have to remark, in the first place, that the colours of nature, and those of objects when represented in a painting, differ in most essential circumstances. Bodies of various colours, when placed together, have their colours reflected from the one to the other; and so they come to the eye. This is one mode in which the hues of nature are harmonized; but the colours upon the flat surface of the canvass cannot be thus reflected and mingled. The next difference results from the atmosphere, through which the rays from distant objects proceed to the eye and are softened; the canvass being near the eye, the

effect which the atmosphere produces on colours amounts to nothing in the picture. The third mode in which colours are affected, is common to natural objects and to paintings, and is connected with the law of vision which we have been considering, and to which we must now revert.

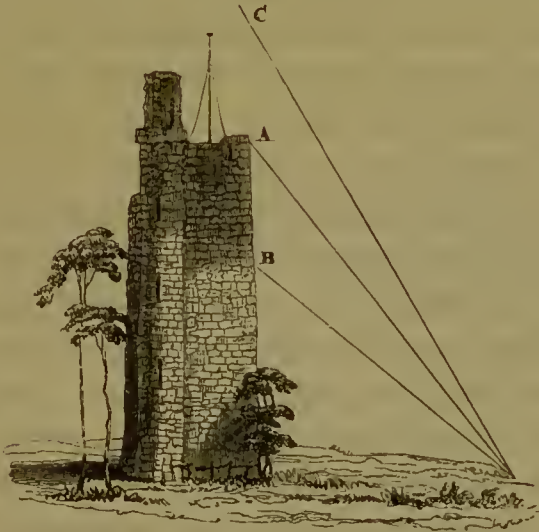
When we make experiments by looking upon coloured spots, the effect on the sensibility of the retina is remarkable ; and as this does not occur incidentally, but takes place more or less, whenever we exercise the eye, it must have its influence when we look to works of art. The familiar fact which we have to carry with us into this inquiry, is, that if we throw a silver coin upon a dark table and fix the eye upon the centre of it, when we remove the coin there is, for a moment, a white spot in its place, which presently becomes deep black. If we put a red wafer upon a sheet of paper and look upon it, and continue to keep the eye fixed on the same point, upon removing the wafer, the spot where it lay on the white paper will appear green. If we look upon a green wafer in the same manner and remove it, the spot will be red ; if upon blue or indigo, the paper will seem yellow. These phenomena are to be explained by considering that the nerve is exhausted by the continuance of the impression, and becomes more apt to

receive sensation from an opposite colour. All the colours of the prism come into the eye from the surface of the white paper when the wafer is removed; but if the nerve has been exhausted by the incidence of the red rays upon it, it will be insensible to these red rays when they are thus reflected from the paper; the effect of the rays of an opposite kind will be increased, and consequently the spot will be no longer white, but of the prevailing green colour.

Let us see how the loss of sensibility produces an effect in engraving, where there is no colour, and only light and shade.

Is it possible that a high tower, in a cloudless sky, can be less illuminated at the top than at the bottom? Yet if we turn to a book of engravings, where an old steeple or tower is represented standing up against the clear sky, we shall find that all the higher part is dark, and that the effect is picturesque and pleasing. Now this is perfectly correct, for although the highest part of the tower be in the brightest illumination, it is not seen so—it never appears so to the eye. The reason is, that when we look to the steeple, a great part of the retina is opposed to the light of the sky; and on shifting the eye to look at the particular parts of the steeple, the reflected light from that object falls upon the retina, where it is exhausted by the direct light of the sky. If we

look to the top of the tower, and then drop the eye to some of the lower architectural ornaments, the effect infallibly is that the upper half of the tower is dark. For example, if looking to the



point A we drop the eye to B: the tower from A to B is seen by that part of the retina which was opposed to the clear sky from A to C; and it is dark not by contrast, as it would be thoughtlessly said, but by the nerve being somewhat exhausted of its sensibility. This, then, is the first effect we shall remark as arising from the searching motion of the eye.

The refreshing colours of the natural landscape are at no time so pleasing as, when reading on a journey, we turn the eye from the book to the fields and woods; the shadows are then deeper

—the greens more soothing, and the whole colours are softened. Reynolds observed to Sir George Beaumont that the pictures of Rubens appeared different to him, and less brilliant, on his second visit to the continent ; and the reason of the difference he discovered to be that, on the first visit, he had taken notes, and on the second he did not. The alleged reason is quite equal to the effect ; but I cannot help imagining that there is some incorrectness in the use of the term brilliant, unless warmth and depth of colouring is meant : for when the eye turns from the white paper to the painting, the reds and yellows must necessarily be deeper. If we look out from the window, and then turn towards a picture, the whole effect is gone—the reflected rays from the picture are too feeble to produce their impression ; and if we look upon a sheet of paper, and then upon a picture, the tone will be deeper, and the warm tints stronger, but the lights and shades less distinct. If we place an oil painting, without the frame, upon a large sheet of paper, or against a white plastered wall, it is offensively yellow. Here the eye alternately, though insensibly, moving from the white paper or wall to the painting, which is of a deep tone, the browns and yellows are unnaturally strong. We see the necessity or the effect of the gilt frame for such a picture : it does not merely cut off surrounding objects, but it prepares the eye

for the colours of the painting—it allows, if I may so express it, the painter to use his art more boldly, and to exaggerate the colours of nature.

Painters proceed by experiment. If they are painting a portrait, they may represent the features by contrasts of lights and shadows with very little colour; but such a portrait is never popular. If they are to represent the features without much contrast of light and shade, they must raise the features by contrasts of colours, and the carnations are necessarily exaggerated; but all this is softened down by throwing a piece of drapery into the picture, and its colours so prepare the eye, that now looking on the features, that appears natural, which, but for this art, would have represented an inflamed countenance. The common resource of the painter is to throw in a crimson curtain, or to introduce some flower or piece of dress that shall lead the eye, by a succession of tints, or, more accurately speaking, shall prepare the eye to receive the otherwise exaggerated colours of the portrait. The eye first surveying the red curtain, and then the countenance, sees it as if coloured only with the modesty of nature.

Those who hang pictures, do not place an historical picture, painted after the manner of the Bolognese school with distinct and abrupt coloured draperies, by the side of a landscape; for

the colours of a landscape, to be at all consonant with nature, are weak and reduced to a low tone, by representing that effect, which we observed, of the intervention of the atmosphere; its colours, therefore, would be destroyed by too powerful a contrast. It is difficult to decide what the colour of the walls of a gallery should be, because the pictures are, for the most part, painted on different principles; but generally speaking, the dark subdued red or morone brings out the colours of paintings; in other words, if we look on a wall of this hue, and then turn to the picture, the prevailing green and yellow tints will appear brighter.

The word "contrast" is used without a definition, or without an exact comprehension of its meaning. Now the effect of colours, on being placed together, is produced through the *motion* of the eye, combined with the law of the sensibility of the retina, to which we have been adverting. When we imagine that we are comparing colours, we are really experiencing the effect of the nerve being exhausted by dwelling on one colour, and becoming more susceptible of the opposite colour. In coloured drapery, for example, there is such a mixture of all colours reflected from it, although one prevails, that the impression may be greatly modified by what the eye has previously experienced. If the colouring of the flesh be, as the painter terms it, too "warm," it may be made "cold" by rendering

the eye insensible to the red and yellow rays, and more than usually susceptible of the blue and purple rays. Every coloured ray from the flesh is transmitted to the eye; but if the eye has moved to it from a yellow or crimson drape, then the rays of that kind will be, for the moment, lost to the vision, and the colour of the flesh will appear less warm, in consequence of the prevalence of the opposite rays of colour.

It ought to be unsatisfactory to the philosophical student to make use of a term without knowing its full meaning. There has been a great deal said about contrast and harmony in painting, as resulting from certain colours placed together—the idea being that we see these colours at the same time—whereas, the effect, of which we are all sensible, results from alternately looking at the one and at the other. The subject might be pleasantly pursued, but I mean only to vindicate the importance of the motions of the eye to our enjoyment, whether of the colours of art or of nature.

There is another subject of some interest, namely, the effect produced upon the retina when the eye is intently fixed upon an object, and is not permitted to wander from point to point. This touches on the chiaroscuro of painting; which is not merely the managing of the lights and shadows, but the preserving of the parts of a scene subordinate to the principal object. There

is something unpleasant and imperfect, even to the least experienced eye, in a picture where every thing is made out—the drapery of every figure, the carving or ornament of all the objects minutely represented : for these things were never so seen in nature. The true picture, on the other hand, is effective and felt to be natural, when the eye is at once led to dwell on that principal group, or principal figure, with which it is the artist's intention to occupy the imagination. By fine mastery of his art, and by insensible degrees, the painter keeps down the parts which are removed from the centre ; and thus he represents the scene as when, looking intently upon an object, we see that which is near the axis of the eye distinctly—the other objects retreating, as it were, or rising out less and less distinctly, in proportion as they recede from the centre. In the one instance, the artist paints a panorama, where on turning round we have presented before the eye the several divisions of the circle, in each of which the objects are equally distinct ; in the other, he paints a picture representing things, not as when the eye wanders from the one part to the other, but where it is fixed with higher interest upon some central object, while the others fall off subordinately.

Looking to our main argument, the proofs of beneficence in the capacities of the living frame, we revert naturally to the pleasures

received through this double property of the eye—motion and sensibility ; and whilst we perceive that the varieties of light and shade are necessary to vision, we find that the coloured rays are also, by their variety, suited to the higher exercise of this sense. They do not all equally illuminate objects, nor are they all equally agreeable to the eye. The yellow, pale green, or isabella colours, illuminate in the highest degree, and are the most agreeable to the sense ; and we cannot but observe, looking out on the face of nature, whether to the country, the sea, or the sky, that they are the prevailing colours.* The red ray illuminates the least, but it irritates the most ; and it is this variety in the influence of these rays upon the nerve, that continues its exercise, and adds so much to our enjoyment. We have pleasure from the succession and contrast of colours, independently of that higher gratification which the mind enjoys through the influence of association.

OF EXPRESSION IN THE EYE.

In the conclusion of the volume I took occasion to remark that natural philosophy sometimes disturbed the mind of a weak person. I recollect a student who objected to the direc-

* The Astronomer selects for his telescope a glass which refracts the pale yellow light in the greatest proportion, because it illuminates in the highest degree and irritates the least.

tion of the eyes upwards, and the attitude of prayer: "For," said he, "it is unmeaning; the globe on which we stand is round, and the inhabitants in every degree or division of the sphere have their eyes directed differently, diverging from the earth, and concentrated to nothing." This foolish observation leads us once more to notice the relations between the mind and the body, and external nature.

The posture and the expression of reverence are universally the same in every period of life, in all stages of society, and in every clime. On first consideration of this subject, it seems merely natural that, when pious thoughts prevail, man's countenance should be turned from things earthly to the purer objects above. But there is a link in this relation every way worthy of attention, and the eye is raised, whether the canopy over us be shrouded in darkness, or display all the splendour of noon.

The muscles which move the eye-ball are powerfully affected in certain conditions of the mind: independently altogether of the will, the eyes are rolled upwards during mental agony, and whilst strong emotions of reverence and piety are felt. This is a natural sign stamped upon the human countenance, and is as peculiar to man, as any thing which distinguishes him from the brute. The posture of the body follows necessarily, and forms one of those many

traits of expression which hold mankind in sympathy.

We might bring forward the same evidence here, that we did on a somewhat similar question regarding the expression of the hand, that is to say, the works of the great painters who have made the sublimer passions of man the subjects of their art ; for by the direction of the eyes and the correspondence of feature and attitude, they speak to all mankind. Thus we must admit that the reverential posture, and the upward direction of the eyes are natural to man whether in the darkened chamber or under the canopy of heaven. They result from the very constitution of the mind and body, and are too powerful to be effaced or altered ; no sooner does pain or misfortune subdue a man, or move him to supplication, than the same universal expression prevails. Here is the correspondence of the mind, the frame, and external nature, by which man is directed to look for aid from above.

APPENDIX.

THE

CLASSIFICATION OF ANIMALS.

IN EXPLANATION OF THE TERMS INCIDENTALLY USED IN THE
VOLUME.

THE ANIMAL KINGDOM is arranged in four Divisions :

Division I. *Vertebral Animals* : so called from their possessing a vertebral column or spine.

Division II. *Molluscous Animals* : such as shell-fish, which are of a soft structure, and without a skeleton. *Etym.* mollis, soft.

Division III. *Articulated Animals* : like the worm or insect : they are without a skeleton, but their skins or coverings are divided and jointed. *Etym.* Articulus, dim. a joint.

Zoophytes Division IV. *Zoophytes* : animals believed to be composed very nearly of a homogeneous pulp, which is moveable and sensible, and resembles the form of a plant. *Etym.* ζωον, *zoon*, a living creature ; φυτόν, *phyton*, a plant.

DIVISION I.

The division of vertebral animals is composed of four Classes : viz., 1. Mammalia, animals which suckle their young. *Etym.* mamma, a teat. 2. Aves. *Etym.* avis, a bird. 3. Reptilia, animals that crawl. *Etym.* from a part of the word repo, to creep. 4. Pisces. *Etym.* piscis, a fish.

The first Class Mammalia, is divided into Orders, which are subdivided into Genera, and these are further divided into Species.

We present the principal Orders with familiar examples.

Bimana, man. *Etym.* bis, double ; manus, hand.

- Quadrumana. *Etym.* quatuor, four; manus, hand. Monkeys, makis or lemurs (*Etym.* lemures, ghosts). The loris tardigradus (tardus, slow; gradior, to walk) is a species of lemur.
- 1 Cheiroptera. *Etym.* χειρ, *cheir*, the hand; πτερον, *pteron*, a wing. The Bats.
- 2 Insectivora. *Etym.* insecta, insects; voro, to eat. Hedgehog; shrew; mole.
- 3 Plantigrade. *Etym.* planta, the sole of the foot; gradior, to walk. Bear; racoon.
- 4 Digitigrade. *Etym.* digitus, the toe, or finger; gradior, to walk. Lion; wolf; dog; weasel.
- 5 Amphibia. *Etym.* ἀμφι, *amphi*, both; βίος, *bios*, life. Walrus; seal.
- Marsupialia. *Etym.* marsupium, a pouch. Kangaroo; opossum.
- Rodentia. *Etym.* rodo, to gnaw. Squirrel; beaver; rat; hare.
- Edentata. *Etym.* edentulus, toothless: animals without the front teeth. Ai; unau; armadillo; ant-eater; tamandua; megatherium (μεγας, *megas*, great; θηριον, *therion*, a wild beast;) megalonyx (μεγας, *megas*, great; ονυξ, *onyx*, a claw); ornithorhynchus (ορνιθος, *ornithos*, of a bird; ρινυχος, *rhynchos*, a beak.)
- Pachydermata. *Etym.* παχυς, *pachys*, thick; δερμα, *derma*, skin. Rhinoceros; elephant; mammoth; mastodon (μαστος, *mastos*, a nipple; οδων, *odon*, a tooth); Anoplotherium (ανοπλος, *anoplos*, unarmed: θηριον, *therion*, wild animal); Palæotherium (παλαιος, *palaios*, ancient: θηριον); tapir; solidungula, as the horse; couagga.
- Ruminantia. *Etym.* ruminatio, chewing the cud. Camel; giraffe; deer; goat; cow; sheep.
- Cetacea. *Etym.* cetus, a whale. Dolphin; whale; dugong.

SECOND CLASS. *Aves*, or *Birds*.

- Accipitres. *Etym.* accipiter, a hawk. Vulture; eagle; owl.
- Passeres. *Etym.* passer, a sparrow. Lark; thrush; swallow; crow; wren.

- Scansores. *Etym.* scando, to climb. Parrot; wood-pecker; toucan.
- Gallinæ. *Etym.* gallina, a hen. Peacock; pheasant; pigeon.
- Grallæ. *Etym.* grallæ, stilts. Ostrich; stork; ibis; flamingo.
- Palmipedes. *Etym.* palma, the palm of the hand; pes, foot. Swan; pelican; gull.

THIRD CLASS. *Reptiles.*

- Chelonia. *Etym.* χελυς, *chelys*, a tortoise. Tortoise; turtle.
- Sauria. *Etym.* σαυρα, *saura*, a lizard. Crocodile; alligator; chameleon; dragon; pterodactyle (περρον, *pteron*, a wing; δακτυλος, *dactylus*, a finger); ichthyosaurus (ιχθυς, *ichthys*, a fish; σαυρα, *saura*, a lizard); plesiosaurus (πλεσιον, *plesion*, near to; σαυρα, *saura*, a reptile, resembling a reptile more than a fish); megalosaurus (μεγαλη, *megale*, great; σαυρα, *saura*, a reptile); iguanodon; hylæosaurus (ύλη, *hyle*, wood or weald, σαυρα).
- Ophidia. *Etym.* οφεις, *ophis*, a serpent. Boa; viper.
- Batrachia. *Etym.* βατραχος, *batrachos*, a frog. Frog; salamander; proteus.

FOURTH CLASS. *Fishes.*

- Chondropterygii. *Etym.* χονδρος, *chondros*, gristle; περρυξ, *pteryx*, the ray of a fin. Ray; sturgeon; shark; lamprey; ammocete (αμμος, *ammos*, sand; κετος, *cetos*, a fish.)
- Plectognathi. *Etym.* πλεκω, *pleco*, to join; γναθος, *gnathos*, the jaw. Sun-fish; trunk-fish.
- Lophobranchi. *Etym.* λοφος, *lophos*, a loop; βραγχια, *branchia*, the gills. Pipe-fish; pegasus.
- Malacopterygii. *Etym.* μαλακος, *malakos*, soft; περρυξ, *pteryx*, the ray of a fin. Salmon; trout; cod; herring; remora.
- Acanthopterygii. *Etym.* ακανθα, *acantha*, a thorn; περρυξ, *pteryx*, the ray of a fin. Perch; sword-fish; mackarel; lophius piscatorius (λοφια, *lophia*, a pennant; piscator, a fisher); chætodon rostratus (χαιτη, *chiæte*, hair; οδων, *odon*, a tooth; rostratus, beaked); zeus ciliaris (cilium, an eye-lash).

DIVISION II.

MOLLUSCOUS ANIMALS.

1st Class. Cephalopoda. *Etym.* κεφαλη, *cephale*, the head ; ποδα, *poda*, the feet. Animals which have their organs of motion arranged round their head.

This Class includes Sepia, or Cuttle-fish. Argonauts (*Αργω*, the ship Argo, *ναυτης*, *nautes*, a sailor). Nautilus (*ναυτης*, *nautes*, a sailor). Ammonite, an extinct Cephalopode which inhabited a shell resembling that of the Nautilus ; coiled like the horns of a ram or those on the statues of Jupiter Ammon ; whence the name. Belemnites : also extinct : the shell is long, straight, and conical (*βελεμνον*, *belemnion*, a dart). Nummulites : likewise extinct ; whole chains of rocks are formed of its shells ; the pyramids of Egypt are built of these rocks (*nummus*, a coin).

2nd Class. Pteropoda. *Etym.* πτερον, *pteron*, a wing ; ποδα, *poda*, feet ; having fins or processes resembling wings on each side of the mouth.

The *Clio Borealis*, which abounds in the North Seas, and is the principal food of the whale.

3rd Class. Gasteropoda. *Etym.* γαστηρ, *gaster*, the stomach ; ποδα, *poda*, the feet. Animals which move by means of a fleshy apparatus placed under the belly.

The snail ; slug ; limpet.

4th Class. Acephala. *Etym.* α, α, without ; κεφαλη, *cephale*, the head. Molluscos animals without a head.

The oyster ; muscle.

5th Class. Brachiopoda. *Etym.* βραχιον, *braehion*, the arm ; ποδα, *poda*, the feet. Animals which move by means of processes like arms.

Lingula ; terebratula.

6th Class. Cirrhopoda. *Etym.* cirrus, a lock or tuft of hair ; ποδα, *poda*, the feet.

Balanus ; barnacle ; anatifera (*anas*, a duck, *fero*, to bring forth).

DIVISION III.

ARTICULATA.

1st Class. Annelides, or Vermes. *Etym.* *Annellus*, a little ring; *vermis*, a worm.

Leech; sea-mouse; earth-worm; sand-worm; tubicolæ, (tubus, a tube, colo, to inhabit); worms which cover themselves, by means of a slimy secretion that exudes from their surfaces, with a case of small shells and pebbles, like the caddis-worm, or with sand and mud.

2nd Class. Crustacea. Animals which have a shelly crust, covering their bodies.

The crabs; shrimps; lobsters.

3rd Class. Arachnida. *Etym.* *αραχνης*, *arachnes*, a spider.

Spiders; *aranca scenica*, or *saltica*, the leaping spider; the scorpion spider; the mite.

4th Class. Insecta. They are divided into insects which are without wings and those which have them: and these are further subdivided according to the peculiarities of the wings.

Aptera (*a, a*, without; *πτερον*, *pteron*, a wing). Centipede (having a hundred feet); louse; flea.

Coleoptera (*κολεος*, *coleos*, a sheath or scabbard, *πτερον*, a wing), insects which have their wings protected by a cover, as the beetle, corn-weevil. *Orthoptera* (*ορθος*, *orthos*, straight, *πτερον*), as the locust, grass-hopper. *Hemiptera* (*ημισυ*, *hemisu*, half, *πτερον*), insects which have one half of their wings thick and coriaceous, and the other membranous; such as a bug, tick, fire-fly. *Neuroptera* (*νευρον*, *neuron*, a nerve, *πτερον*), dragon-fly; ant-lion; ephemera. *Hymenoptera* (*υμεν*, *hymen*, a membrane, *πτερον*), the bee; wasp; ant. *Lepidoptera* (*λεπισ*, *lepis*, a scale, *πτερον*), moth; butter-fly. *Rhipiptera* (*ριπισ*, *ripis*, a fan, *πτερον*), xenos; stylops. *Diptera* (*δεις*, *dis*, double, *πτερον*), house-fly; gnat.

DIVISION IV.

ZOOPHYTES.

Echinodermata (Etym. εχινος, *echinos*, a hedgehog; δερμα, *derma*, the skin), the star-fish; sea urchin. *Entozoa* (εντος, *entos*, within; ζαω, *zao*, to live), tænia; hydatid. *Acalephæ* (ακαληφη, *acalephe*, a nettle), medusa; polypi (containing much sap); sea-anemone; hydra; tubipora (inhabiting tubes); sertularia; cellularia; flustra; coralline, sponge. *Infusoria* (found in infusions or stagnant water), monas; vibrio; proteus.

THE END.

