Date Due

NATURAL THEOLOGY;

OR

EVIDENCES

OF THE

EXISTENCE AND ATTRIBUTES

OF

THE DEITY,

COLLECTED FROM THE APPEARANCES OF NATURE.

BY WILLIAM PALEY, D. D.

ILLUSTRATED BY A

SERIES OF PLATES, AND EXPLANATORY NOTES,

BY JAMES PAXTON,

MEMBER OF THE ROYAL COLLEGE OF SURGEONS, LONDON.

VOL. I.

THIRD EDITION.

OXFORD:

PRINTED FOR J. VINCENT;

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1836.

OXFORD:
PRINTED BY J. VINCENT.

TO THE

HONOURABLE AND RIGHT REVEREND

SHUTE BARRINGTON, LL. D.

LORD BISHOP OF DURHAM.

My Lord,

To your suggestion the world is indebted for the existence of Dr. Paley's valuable work on Natural Theology. The universal and permanent esteem in which it has been held in this country, and its favourable reception in France, even after the desolating influence of the Revolution, have abundantly approved your Lordship's selection both of the subject and of the person to whom you intrusted it.

In looking round, then, for a patron for these Illustrations, it was natural to have recourse to him who was the original suggestor of the work which it is their object to explain. Nor was I disappointed in my wish; your Lordship not only condescending to approve of the design but to encourage me in its prosecution, by your very liberal support. For this distinguished honour you will believe me deeply sensible; and if I may indulge the hope that my humble efforts will increase the utility of so eminent a writer, I shall consider it the highest gratification.

I am,

My Lord,

With great veneration,

Your Lordship's most obliged

And obedient servant,

JAMES PAXTON,

Oxford,
January 1, 1826.

PREFACE.

The works of Dr. Paley have acquired that popularity which renders it scarcely necessary to observe that his Natural Theology was written to establish the truth of the agency and wisdom of the Deity from the admirable contrivances and mechanism displayed in natural objects, inferring from thence that the knowledge and power requisite for the formation of created nature must be infinite.

The principal physical arguments made use of, relate to organs destined to mechanical functions, as the bones of man—the muscles—the structure of animals, or comparative anatomy—prospective and compensatory contrivances—insects and plants: with most of these objects the anatomist only can be conversant; but all admit of graphic representation, and such has been attempted.

The designs of the following plates are original, obtained from the most authentic sources, and submitted to the critical examination of the most competent judges. It is hoped that the illustrations will be found the more interesting from their being simple and unincumbered by parts irrelevant to the subject of the author. These are accompanied by notes, which are intended to supply defective or correct erroneous statements, and to explain the plates.

The undertaking originated in the difficulty of understanding the various descriptions introduced by Paley, not however from his want of clearness, for the subjects in general are plainly and correctly described; but it is evident that visible representations strike the mind more forcibly than mere descriptions. It is therefore presumed that the subsequent illustrations will be an acquisition, by bringing vividly to the imagination, objects of which only an imperfect idea could otherwise be formed; and that they will consequently render the work more intelligible to the general reader.

PREFACE

TO THE SECOND EDITION.

It cannot be necessary to insist on the superior character and merits of the NATURAL THEOLOGY of DR. PALEY. The high estimation in which the original work has been held, from the first publication to the present time, supersedes any encomium. The ILLUSTRATIONS and NOTES consequently met with a reception proportionably favourable; its success indeed exceeded every expectation the editor had entertained; and it becomes a matter of surprise, that so popular an author had not before received the aid of plates to exhibit animal mechanism, and vegetable formation, with notes to bring the physical statements down to the present advanced stage of natural knowledge; for it was well known, that with the utmost attention, the fancy could not follow the author in his descriptions of structure and functions, especially when complicated contrivance, either in animal or vegetable nature, were to be unfolded. To comprehend the subject thoroughly also required a somewhat deeper acquaintance with the several sciences of anatomy, entomology, and botany, than most persons can be supposed to possess. The editor therefore trusts, that the illustrations and notes, particularly in their improved state, will be found to meet the difficulty and supply the deficiency.

In presenting the second edition to the public, the editor believes that the notes have not been enlarged without giving increasing value and interest to the text. The references have been corrected, a number of new figures introduced, and two plates added, containing such objects which have been pointed out as being required to render the book more complete.

Several corrections and additions have been made from suggestions in the Edinburgh Review, &c. In the Entomological department the editor begs to acknowledge his obligations to A. Ingpen, Esq. and for several of the Botanical notes he is indebted to Mr. Baxter, of the Botanical Gardens of the University of Oxford.

Oxford,
June, 1, 1828.

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TO THE

HONOURABLE AND RIGHT REVEREND

SHUTE BARRINGTON, LL. D.

LORD BISHOP OF DURHAM.

MY LORD,

THE following Work was undertaken at your Lordship's recommendation, and, amongst other motives, for the purpose of making the most acceptable return that I could, for a great and important benefit conferred upon me.

It may be unnecessary, yet not perhaps quite impertinent, to state to your Lordship, and to the reader, the several inducements that have led me once more to the press. The favour of my first and ever-honoured Patron had put me in possession of so liberal a provision in the Church, as abundantly to satisfy my wants, and much to exceed my pretensions. Your Lordship's munificence, in conjunction with that of some other excellent Prelates, who regarded my services with the partiality with which your Lordship was pleased to consider them, hath since placed me in ecclesiastical situations, more than adequate to every object of reasonable ambition. In the mean time, a weak, and, of late, a painful state of health, deprived me of the power of discharging the duties of my station in a manner at all suitable, either to my sense of those duties, or to my most anxious wishes concerning them. My inability for the public functions of my profession, amongst other consequences, left me much at leisure. That leisure was not to be lost. It was only in my study that I could repair my deficiencies in the Church; it was only through the press that I could speak. These circumstances entitled your Lordship in particular to call upon me for the only species of exertion of which I was capable, and disposed me without hesitation to obey the call in the best manner that I could. In the choice of a subject I had no place left for doubt: in saying which, I do not so much refer, either to the supreme importance of the subject, or to any scepticism concerning it with which the present times are charged, as I do to its connexion with the subjects treated of in my former publications. The following discussion alone was wanted to make up my works into a system: in which works, such as they are, the public have now before them, the Evidences of Natural Religion, the Evidences of Revealed Religion, and an account of the duties that result from both. It is of small importance that they have been written in an order the very reverse of that in which they ought to be read. I commend, therefore, the present volume to your Lordship's protection, not only as, in all probability, my last labour, but as the completion of a regular and comprehensive design.

Hitherto, my Lord, I have been speaking of myself, and not of my Patron. Your Lordship wants not the testimony of a Dedication; nor any testimony from me: I consult, therefore, the impulse of my own mind alone when I declare, that in no respect has my intercourse with your Lordship been more gratifying to me, than in the opportunities which it has afforded me, of observing your earnest, active, and unwearied solicitude, for the advancement of substantial Christianity; a solicitude, nevertheless, accompanied with that candour of mind, which suffers no subordinate differences of opinion, when there is a coincidence in the main intention and object, to produce any alienation of esteem, or diminution of favour. It is fortunate for a country, and honourable to its government, when qualities and dispositions like these are placed in high and influencing stations. Such is the sincere judgment which I have formed of your Lordship's character, and of its public value: my personal obligations I can never forget. Under a due sense of both these considerations, I beg leave to subscribe myself, with great respect and gratitude,

My Lord,

Your Lordship's faithful

And most devoted servant,

WILLIAM PALEY.

Bishop-Wearmouth,
July, 1802.

NATURAL THEOLOGY.

CHAPTER I.

STATE OF THE ARGUMENT.

In crossing a heath, suppose I pitched my foot against a *stone*, and were asked how the stone came to be there; I might possibly answer, that, for any thing I knew to the contrary, it had lain there for ever; nor would it perhaps be very easy to show the absurdity of this answer. But suppose I had found a *watch* upon the ground, and it should be inquired how the watch happened to be in that place; I should hardly think of the answer which I had before given, that for anything I knew, the watch might have always been there. Yet why should not this answer serve for the watch as well as for the stone? why is it not as admissible in the second case, as in the first? For this reason, and for no other, viz. that, when we come to inspect the watch, we perceive (what we could not discover in the stone) that its several parts are framed and put together for a purpose, *e. g.* that they are so formed and adjusted as to produce motion, and that motion so regulated as to point out the hour of the day: that if the different parts had been differently shaped from what they are, of a different size from what they are, or placed after any other manner, or in any other order than that in which they are placed, either no motion at all would have been carried on in the machine, or none which would have answered the use that is now served by it. To reckon up a few of the plainest of these parts, and of their offices, all tending to one result:—we see a cylindrical box containing a coiled elastic spring, which, by its endeavour to relax itself, turns round the box.* We next observe a flexible chain (artificially wrought for the sake of flexure) communicating the action of the spring from the box to the fusee.† We then find a series of wheels,‡ the

* Tab. I. Fig. 1. The *box*, or *barrel*, containing the main spring, which is the first power; and the *chain* which communicates the power to—

† Fig. 2. The *fusee* and *great* wheel. The fusee is tapered at the top to correct the irregular recoil of the spring. The great wheel turns—

‡ Fig. 3. The *centre* wheel and pinion, which makes one revolution in an hour, carries the minute hand, and turns—

Fig. 4. The *third* wheel and pinion, which turns the contrite wheel.

Fig. 5. The *contrite* wheel, which makes one revolution in a minute, and turns the balance or escape wheel.

Fig. 6. The *balance* wheel, which acts upon the pallets of the verge, and escapes, or drops from one pallet to another alternately, thereby keeping the balance in constant vibration.

TAB. I

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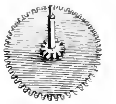

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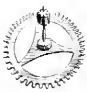

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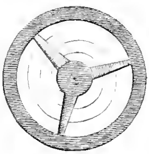

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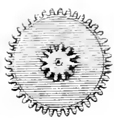

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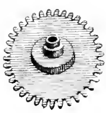

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teeth of which catch in, and apply to, each other, conducting the motion from the fusee to the balance,* and from the balance to the pointer;† and at the same time, by the size and shape of those wheels, so regulating that motion, as to terminate in causing an index, by an equable and measured progression, to pass over a given space in a given time. We take notice that the wheels are made of brass in order to keep them from rust: the springs of steel, no other metal being so elastic; that over the face of the watch there is placed a glass, a material employed in no other part of the work, but in the room of which, if there had been any other than a transparent substance, the hour could not be seen without opening the case. This mechanism being observed (it requires indeed an examination of the instrument, and perhaps some previous knowledge of the subject, to perceive and understand it; but being once, as we have said, observed and understood,) the inference, we think, is inevitable,

* Fig. 7. The *balance verge*, and *balance* or *pendulum spring*, which regulates the whole machine.

† Fig. 8. The *cannon pinion*, affixed to the centre wheel arbour, on which the minute hand is placed.

Fig. 9. The *minute* wheel.

Fig. 10. The *hour* wheel. The two last mentioned wheels are turned by the cannon pinion, and having a greater number of teeth, move much slower than the cannon pinion, and mark the hour by the hand on the dial.

The above is a description of the several wheels alluded to by Paley. Their relative situation, and combined movement, may be seen by the simple inspection of a watch.

that the watch must have had a maker: that there must have existed, at some time, and at some place or other, an artificer or artificers, who formed it for the purpose which we find it actually to answer; who comprehended its construction, and designed its use.

I. Nor would it, I apprehend, weaken the conclusion, that we had never seen a watch made; that we had never known an artist capable of making one: that we were altogether incapable of executing such a piece of workmanship ourselves, or of understanding in what manner it was performed; all this being no more than what is true of some exquisite remains of ancient art, of some lost arts, and, to the generality of mankind, of the more curious productions of modern manufacture. Does one man in a million know how oval frames are turned? Ignorance of this kind exalts our opinion of the unseen and unknown artist's skill, if he be unseen and unknown, but raises no doubt in our minds of the existence and agency of such an artist, at some former time, and in some place or other. Nor can I perceive that it varies at all the inference, whether the question arise concerning a human agent, or concerning an agent of a different species, or an agent possessing, in some respects, a different nature.

II. Neither, secondly, would it invalidate our conclusion, that the watch sometimes went wrong, or that it seldom went exactly right. The purpose of the machinery, the design and the designer, might be evident, and in the case supposed would be evident, in whatever way we accounted for the irregularity of the movement, or whether we could account for it or not. It is not necessary that a machine be perfect, in order to shew with what design it was made: still less necessary, where the only question is, whether it were made with any design at all.

III. Nor, thirdly, would it bring any uncertainty into the argument, if there were a few parts of the watch, concerning which we could not discover, or had not yet discovered, in what manner they conduced to the general effect; or even some parts, concerning which we could not ascertain, whether they conduced to that effect in any manner whatever. For, as to the first branch of the case; if by the loss, or disorder, or decay of the parts in question, the movement of the watch were found in fact to be stopped, or disturbed, or retarded, no doubt would remain in our minds, as to the utility or intention of these parts, although we should be unable to investigate the manner according to which, or the connexion by which, the ultimate effect depended upon their action or assistance; and the more complex is the machine, the more likely is this obscurity to arise. Then, as to the second thing supposed, namely, that there were parts which might be spared, without prejudice to the movement of the watch, and that we had proved this by experiment—these superfluous parts, even if we were completely assured that they were such, would not vacate the reasoning which we had instituted concerning other parts. The indication of contrivance remained, with respect to them, nearly as it was before.

IV. Nor, fourthly, would any man in his senses think the existence of the watch, with its various machinery, accounted for, by being told that it was one out of possible combinations of material forms; that whatever he had found in the place where he found the watch, must have contained some internal configuration or other; and that this configuration might be the structure now exhibited, viz. of the works of a watch, as well as a different structure.

V. Nor, fifthly, would it yield his enquiry more satisfaction to be answered, that there existed in things a principle of order, which had disposed the parts of the watch into their present form and situation. He never knew a watch made by the principle of order; nor can he even form to himself an idea of what is meant by a principle of order distinct from the intelligence, of the watchmaker.

VI. Sixthly, he would be surprised to hear that the mechanism of the watch was no proof of contrivance, only a motive to induce the mind to think so.

VII. And not less surprised to be informed, that the watch in his hand was nothing more than the result of the laws of *metallic* nature. It is a perversion of language to assign any law as the efficient, operative cause of any thing. A law pre-supposes an agent; for it is only the mode according to which an agent proceeds: it implies a power; for it is the order, according to which that power acts. Without this agent, without this power, which are both distinct from itself, the *law* does nothing; is nothing. The expression "the law of metallic nature," may sound strange and harsh to a philosophic ear; but it seems quite as justifiable as some others which are more familiar to him, such as "the law of vegetable nature," "the law of animal nature," or indeed as "the law of nature" in general, when assigned as the cause of phenomena, in exclusion of agency and power; or when it is substituted into the place of these.

VIII. Neither, lastly, would our observer be driven out of his conclusion, or from his confidence in its truth, by being told that he knew nothing at all about the matter. He knows enough for his argument: he knows the utility of the end: he knows the subserviency and adaptation of the means to the end. These points being known, his ignorance of other points, his doubts concerning other points, affect not the certainty of his reasoning. The consciousness of knowing little need not beget a distrust of that which he does know.

CHAPTER II.

STATE OF THE ARGUMENT CONTINUED.

Suppose, in the next place, that the person who found the watch, should, after some time, discover that, in addition to all the properties which he had hitherto observed in it, it possessed the unexpected property of producing, in the course of its movement, another watch like itself, (the thing is conceivable;) that it contained within it a mechanism, a system of parts, a mould for instance, or a complex adjustment of laths, files, and other tools, evidently and separately calculated for this purpose; let us inquire, what effect ought such a discovery to have upon his former conclusion,

I. The first effect would be to increase his admiration of the contrivance, and his conviction of the consummate skill of the contriver. Whether he regarded the object of the contrivance, the distinct apparatus, the intricate, yet in many parts intelligible mechanism, by which it was carried on, he would perceive, in this new observation, nothing but an additional reason for doing what he had already done,—for referring the construction of the watch to design, and to supreme art. If that construction *without* this property, or, which is the same thing, before this property had been noticed, proved intention and art to have been employed about it; still more strong would the proof appear, when he came to the knowledge of this further property, the crown and perfection of all the rest.

II. He would reflect, that though the watch before him were, *in some sense*, the maker of the watch which was fabricated in the course of its movements, yet it was in a very different sense from that in which a carpenter, for instance, is the maker of a chair; the author of its contrivance, the cause of the relation of its parts to their use. With respect to these, the first watch was no cause at all to the second: in no such sense as this was it the author of the constitution and order, either of the parts which the new watch contained, or of the parts by the aid and instrumentality of which it was produced. We might possibly say, but with great latitude of expression, that a stream of water ground corn; but no latitude of expression would allow us to say, no stretch of conjecture could lead us to think, that the stream of water built the mill, though it were too ancient for us to know who the builder was. What the stream of water does in the affair, is neither more nor less than this; by the application of an unintelligent impulse to a mechanism previously arranged, arranged independently of it, and arranged by intelligence, an effect is produced, viz. the corn is ground. But the effect results from the arrangement. The force of the stream cannot be said to be the cause or author of the effect, still less of the arrangement. Understanding and plan in the formation of the mill were not the less necessary, for any share which the water has in grinding the corn; yet is this share the same as that which the watch would have contributed to the production of the new watch, upon the supposition assumed in the last section. Therefore,

III. Though it be now no longer probable, that the individual watch, which our observer had found, was made immediately by the hand of an artificer, yet doth not this alteration in any-wise affect the inference, that an artificer had been originally employed and concerned in the production. The argument from design remains as it was. Marks of design and contrivance are no more accounted for now than they were before. In the same thing, we may ask for the cause of different properties. We may ask for the cause of the colour of a body, of its hardness, of its heat; and these causes may be all different. We are now asking for the cause of that subserviency to a use, that relation to an end, which we have remarked in the watch before us. No answer is given to this question, by telling us that a preceding watch produced it. There cannot be design without a designer; contrivance, without a contriver; order, without choice; arrangement, without any thing capable of arranging: subserviency and relation to a purpose, without that which could intend a purpose; means suitable to an end, and executing their office in accomplishing that end, without the end ever having been contemplated, or the means accommodated to it. Arrangement, disposition of parts, subserviency of means to an end, relation of instruments to a use, imply the presence of intelligence and mind. No one, therefore, can rationally believe, that the insensible, inanimate watch, from which the watch before us issued, was the proper cause of the mechanism we so much admire in it;—could be truly said to have constructed the instrument, disposed its parts, assigned their office, determined their order, action, and mutual dependency, combined their several motions into one result, and that also a result connected with the utilities of other beings. All these properties, therefore, are as much unaccounted for as they were before.

IV. Nor is any thing gained by running the difficulty farther back, *i. e.* by supposing the watch before us to have been produced from another watch, that from a former, and so on indefinitely. Our going back ever so far brings us no nearer to the least degree of satisfaction upon the subject. Contrivance is still unaccounted for. We still want a contriver. A designing mind is neither supplied by this supposition, nor dispensed with. If the difficulty were diminished the farther we went back, by going back indefinitely we might exhaust it. And this is the only case to which this sort of reasoning applies. Where there is a tendency, or, as we increase the number of terms, a continual approach towards a limit, *there*, by supposing the number of terms to be what is called infinite, we may conceive the limit to be attained: but where there is no such tendency, or approach, nothing is effected by lengthening the series. There is no difference, as to the point in question, (whatever there may be as to many points,) between one series and another; between a series which is finite, and a series which is infinite. A chain, composed of an infinite number of links, can no more support itself, than a chain composed of a finite number of links. And of this we are assured, (though we never *can* have tried the experiment,) because, by increasing the number of links, from ten for instance to a hundred, from a hundred to a thousand, &c. we make not the smallest approach, we observe not the smallest tendency, towards self-support. There is no difference in this respect (yet there may be a great difference in several respects) between a chain of a greater or less length, between one chain and another, between one that is finite and one that is infinite. This very much resembles the case before us. The machine which we are inspecting demonstrates, by its construction, contrivance and design. Contrivance must have had a contriver; design, a designer; whether the machine immediately proceeded from another machine or not. That circumstance alters not the case. That other machine may, in like manner, have proceeded from a former machine: nor does that alter the case; contrivance must have had a contriver. That former one from one preceeding it; no alteration still; a contriver is still necessary. No tendency is perceived, no approach towards a diminution of this necessity. It is the same with any and every succession of these machines; a succession of ten, of a hundred, of a thousand; with one series as with another; a series which is finite, as with a series which is infinite. In whatever other respects they may differ, in this they do not. In all, equally, contrivance and design are unaccounted for.

The question is not simply, how came the first watch into existence? which question, it may be pretended, is done away by supposing the series of watches thus produced from one another to have been infinite, and consequently to have had no such *first*, for which it was necessary to provide a cause. This, perhaps, would have been nearly the state of the question, if nothing had been before us but an unorganized, unmechanized substance, without mark or indication of contrivance. It might be difficult to show that such substance could not have existed from eternity, either in succession (if it were possible, which I think it is not, for unorganized bodies to spring from one another) or by individual perpetuity. But that is not the question now. To suppose it to be so, is to suppose that it made no difference whether he had found a watch or a stone. As it is, the metaphysics of that question have no place; for, in the watch which we are examining, are seen contrivance, design; an end, a purpose; means for the end, adaptation to the purpose. And the question which irresistibly presses upon our thoughts, is, whence this contrivance and design? The thing required is the intending mind, the adapting hand, the intelligence by which that hand was directed. This question, this demand, is not shaken off, by increasing a number or succession of substances, destitute of these properties; nor the more, by increasing that number to infinity. If it be said, that upon the supposition of one watch being produced from another in the course of that other's movements, and by means of the mechanism within it, we have a cause, for the watch in my hand, viz. the watch from which it proceeded: I deny, that for the design, the contrivance, the suitableness of means to an end, the adaptation of instruments to a use, (all which we discover in the watch,) we have any cause whatever. It is in vain, therefore, to assign a series of such causes, or to allege that a series may be carried back to infinity; for I do not admit that we have yet any cause at all of the phenomena, still less any series of causes either finite or infinite. Here is contrivance, but no contriver; proofs of design, but no designer.

V. Our observer would further also reflect, that the maker of the watch before him, was, in truth and reality, the maker of every watch produced from it; there being no difference (except that the latter manifests a more exquisite skill) between the making of another watch with his own hands, by the mediation of files, lathes, chisels, &c. and the disposing, fixing, and inserting of these instruments, or of others equivalent to them, in the body of the watch already made, in such a manner as to form a new watch in the course of the movements which he had given to the old one. It is only working by one set of tools instead of another.

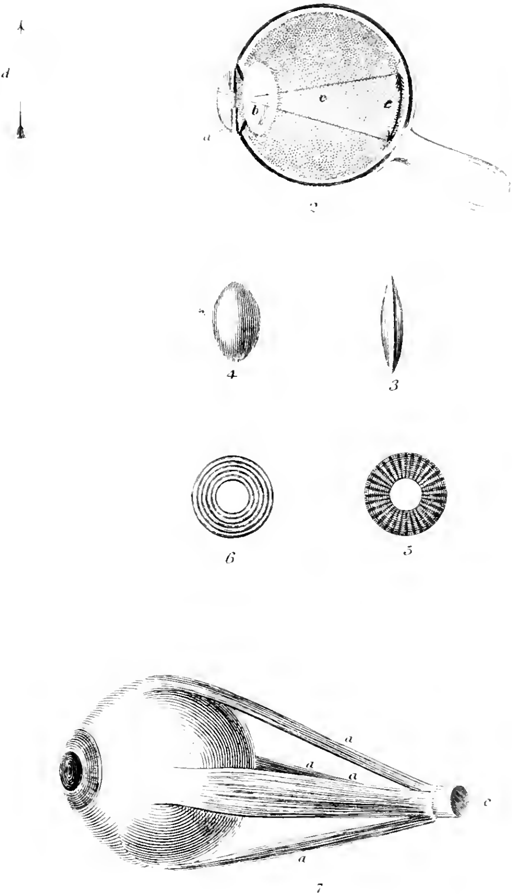
The conclusion which the *first* examination of the watch, of its works, construction, and movement, suggested, was, that it must have had, for the cause and author of that construction, an artificer, who understood its mechanism, and designed its use. This conclusion is invincible. A *second* examination presents us with a new discovery. The watch is found, in the course of its movement, to produce another watch, similar to itself; and not only so, but we perceive in it a system or organization, separately calculated for that purpose. What effect would this discovery have, or ought it to have, upon our former inference? What, as hath already been said, but to increase, beyond measure, our admiration of the skill which had been employed in the formation of such a machine! Or shall it, instead of this, all at once turn us round to an opposite conclusion, viz. that no art or skill whatever has been concerned in the business, although all other evidences of art and skill remain as they were, and this last and supreme piece of art be now added to the rest? Can this be maintained without absurdity? Yet this is atheism.

CHAPTER III.

APPLICATION OF THE ARGUMENT.

This is atheism: for every indication of contrivance, every manifestation of design, which existed in the watch, exists in the works of nature; with the difference, on the side of nature of being greater or more, and that in a degree which exceeds all computation. I mean, that the contrivances of nature surpass the contrivances of art, in the complexity, subtilty, and curiosity of the mechanism; and still more, if possible, do they go beyond them in number and variety: yet, in a multitude of cases, are not less evidently mechanical, not less evidently contrivances, not less evidently accommodated to their end, or suited to their office, than are the most perfect productions of human ingenuity.

TAB. II



I know no better method of introducing so large a subject, than that of comparing a single thing with a single thing; an eye for example, with a telescope. As far as the examination of the instrument goes, there is precisely the same proof that the eye was made for vision, as there is that the telescope was made for assisting it. They are made upon the same principles; both being adjusted to the laws by which the transmission and refraction of rays of light are regulated. I speak not of the origin of the laws themselves; but such laws being fixed, the construction, in both cases, is adapted to them. For instance; these laws require, in order to produce the same effect, that the rays of light, in passing from water into the eye, should be refracted by a more convex surface than when it passes out of air into the eye. Accordingly we find that the eye of a fish,* in that part of it called the crystalline lens, is much rounder than the eye of terrestrial animals. What plainer manifestation of design can there be than this difference? What could a mathematical instrument-maker have done more, to shew his knowledge of his principle, his application of that knowledge, his suiting of his means to his end; I will not say to display the compass or excellence of his skill and art, for in these all comparison is indecorous, but to testify counsel, choice, consideration, purpose?

* Tab. II. 1. The *crystalline lens of a fish;* it is proportionably larger than in other animals, and perfectly spherical.

To some it may appear a difference sufficient to destroy all similitude between the eye and the telescope, that the one is a perceiving organ, the other an unperceiving instrument. The fact is, that they are both instruments. And, as to the mechanism, at least as to mechanism being employed, and even as to the kind of it, this circumstance varies not the analogy at all. For, observe what the constitution of the eye is. It is necessary, in order to produce distinct vision, that an image or picture of the object be formed at the bottom of the eye.* Whence this necessity arises, or how the picture is connected with the sensation, or contributes to it, it may be difficult, nay we will confess, if you please, impossible for us to search out. But the present question is not concerned in the inquiry. It may be true, that, in this, and in other instances, we trace mechanical contrivance a certain way; and that then we come to some-

* Fig. 2. A section of the human eye. It is formed of various *coats*, or membranes, containing pellucid humours of different degrees of density, and calculated for collecting the rays of light into a focus upon the nerve situated at the bottom of the eye-ball.

The external membrane, called *sclerotic*, is strong and firm, and is the support of the spherical figure of the eye; it is deficient in the centre, but that part is supplied by the *cornea*, which is transparent and projects like the segment of a small globe from one of larger size. The interior of the sclerotic is lined by the *choroid*, which is covered by a dark mucous secretion, termed *pigmentum nigrum*, intended to absorb the superfluous rays of light. The *choroid* is represented in the plate by the black line. The the third and inner membrane, which is marked by the white line, is the *retina*, the expanded optic nerve.

thing which is not mechanical, or which is inscrutable. But this affects not the certainty of our investigation, as far as we have gone. The difference between an animal and an automatic statue, consists in this,—that, in the animal, we trace the mechanism to a certain point, and then we are stopped; either the mechanism becoming too subtile for our discernment, or something else beside the known laws of mechanism taking place: whereas, in the automaton, for the comparatively few motions of which it is capable, we trace the mechanism throughout. But, up to the limit, the reasoning is as clear and certain in the one case as in the other. In the example before us, it is a matter of certainty, because it is a matter which experience and observation demonstrate that the formation of an image at the bottom of the eye is necessary to perfect vision. The image itself can be shewn. Whatever affects the distinctness of the image, affects the distinctness of the vision. The formation then of such an image being necessary (no matter how) to the sense of sight, and to the exercise of that sense, the apparatus by which it is formed is constructed and put together, not only with infinitely more art, but upon the self-same principles of art, as in the telescope or the camera obscura. The perception arising from the image may be laid out of the question; for the production of the image, these are instruments of the same kind. The end is the same; the means are the same. The purpose in both is alike; the contrivance for the accomplishing that purpose is in both alike. The lens of the telescope,* and the lens of the eye,† bear a near resemblance to one another, in their figure, their position, and in their power over the rays of light, viz. in bringing each pencil to a point at the right distance from the lens; viz. in the eye, at the exact place where the membrane is spread to receive it. How is it possible, under circumstances of such close affinity, and under the operation of equal evidence, to exclude contrivance from the one, yet to acknowledge the proof of contrivance having been employed, as the plainest and clearest of all propositions, in the other?

The resemblance between the two cases is still more accurate, and obtains in more points than we have yet represented, or than we are, on the first view of the subject, aware of. In dioptric telescopes, there is an imperfection of this nature. Pencils of light, in passing through glass lenses, are separated into different colours, thereby tinging the

* See Fig. 3.

† Fig. 4. The crystalline *lens*, or, as it has been called, the crystalline *humour*, of the eye. The comparison with the lens of the telescope is not perfectly exact, for the crystalline lens is a substance composed of concentric layers, of unequal density, the hardness of which increases from the surface to the centre; and hence possesses a more refractive power than any artificial lens. Mr. Ramsden supposes that this texture tends to correct the aberration occasioned by the spherical form of the cornea, and the focus of each oblique pencil of rays falls accurately on the concave surface of the retina.

object, especially the edges of it, as if it were viewed through a prism. To correct this inconvenience had been long a desideratum in the art. At last it came into the mind of a sagacious optician, to inquire how this matter was managed in the eye; in which, there was the same difficulty to contend with, as in the telescope. His observation taught him, that, in the eye, the evil was cured by combining lenses composed of different substances, *i. e.* of substances which possessed different refracting powers. Our artist borrowed thence his hint; and produced a correction of the defect by imitating, in glasses made from different materials, the effects of the different humours* through which the rays of light pass before they reach the bottom of the eye. Could this be in the eye without purpose, which suggested to the optician the only effectual means of attaining that purpose?

But further; there are other points, not so much perhaps of strict resemblance between the two, as of superiority of the eye over the telescope; yet

* Within the coats of the eye which have been mentioned, are the *humours*. Fig. 2. *a*, the *aqueous* humour, which is a thin fluid like water; *b*, the *crystalline lens*, of a dense texture; c, the *vitreous* humour, a very delicate gelatinous substance named from its resemblance to melted glass. Thus the crystalline is more dense than the vitreous, and the vitreous more dense than the aqueous humour; they are all perfectly transparent, and together make a compound lens, which refracts the rays of light issuing from an object, *d*, and delineates its figure, *e*, in the focus upon the retina, inverted.

of a superiority which, being founded in the laws that regulate both, may furnish topics of fair and just comparison. Two things were wanted to the eye, which were not wanted, (at least in the same degree) to the telescope: and these were the adaptation of the organ, first, to different degrees of light; and, secondly, to the vast diversity of distance at which objects are viewed by the naked eye, viz. from as few inches to as many miles. These difficulties present not themselves to the maker of the telescope. He wants all the light he can get; and he never directs his instrument to objects near at hand. In the eye, both these cases were to be provided for; and for the purpose of providing for them, a subtile and appropriate mechanism is introduced:—

I. In order to exclude excess of light, when it is excessive, and to render objects visible under obscurer degrees of it, when no more can be had, the hole or aperture in the eye, through which the light enters, is so formed, as to contract or dilate itself for the purpose of admitting a greater or less number of rays at the same time. The chamber of the eye is a camera obscura,* which, when the light is too small, can enlarge its open-

* As the rays of light flowing from all the points of an object through the *pupil* of the eye, by the refraction of the lens and humours of the eye, form an exact representation at the bottom of the eye on the retina; so the camera obscura, by means of a lens refracting the rays, exhibits a picture of the scene before it on the opposite wall.

ing; when too strong, can again contract it; and that without any other assistance than that of its own exquisite machinery. It is further also, in the human subject, to be observed, that this hole in the eye, which we call the pupil, under all its different dimensions, retains its exact circular shape.*

This is a structure extremely artificial. Let an artist only try to execute the same; he will find that his threads and strings must be disposed with great consideration and contrivance to make a circle, which will continually change its diameter, yet preserve its form. This is done in the eye by an application of fibres, *i. e.* of strings, similar, in their position and action, to what an artist would and must employ, if he had the same piece of workmanship to perform.†

II. The second difficulty which has been stated,

* The pupil of the eye is the aperture formed by the inner margin of the *iris*. See Fig. 5, 6; which shew the arrangement of the fibres of the *iris*.

† Some eminent anatomists have doubted the muscularity of the iris, and have given very different explanations of its motions attributing the contraction and dilatation either to the varied impulse of the blood in its vessels, or to its own vita propria. The enlightened physiologist Magendie affirms, that the latest researches upon the anatomy of the iris proves its muscular structure, and that it is composed of two layers of fibres, the external (Fig. 5.) *radiated*, which dilate the pupil, the other (Fig. 6.) *circular*, which contract the pupil. The external circular fibres appear to be supported by a species of ring, which each of the radiated fibres contributes to form, and in which they slide during the alternate contractions and relaxations of the pupil. See a beautiful plate in Dr. A. Monro's Elements of Anatomy, vol. ii. p. 543.

was the suiting of the same organ to the perception of objects that lie near at hand, within a few inches, we will suppose, of the eye, and of objects which are placed at a considerable distance from it, that, for example, of as many furlongs; (I speak in both cases of the distance at which distinct vision can be exercised.) Now this, according to the principles of optics, that is, according to the laws by which the transmission of light is regulated, (and these laws are fixed,) could not be done without the organ itself undergoing an alteration and receiving an adjustment, that might correspond with the exigency of the case, that is to say, with the different inclination, to one another under which the rays of light reached it. Rays issuing from points placed at a small distance from the eye, and which consequently must enter the eye in a spreading or diverging order, cannot, by the same optical instrument in the same state, be brought to a point, *i. e.* be made to form an image, in the same place with rays proceeding from objects situated at a much greater distance, and which rays arrive at the eye in directions nearly (and physically speaking) parallel. It requires a rounder lens to do it. The point of concourse behind the lens, must fall critically upon the retina, or the vision is confused;* yet, other things re-

* The focus of the refracted rays must fall exactly on the retina, so that the point of vision may be neither produced beyond it, nor shortened so as not to reach it. The latter defect exists in short-

maining the same, this point, by the immutable properties of light, is carried farther back when the rays proceed from a near object than when they are sent from one that is remote. A person who was using an optical instrument, would manage this matter by changing, as the occasion required, his lens or his telescope; or by adjusting the distance of his glasses with his hand or his screw: but how is it to be managed in the eye? What the alteration was, or in what part of the eye it took place, or by what means it was effected, (for if the known laws which govern the refraction of light be maintained, some alteration in the state of the organ there must be,) had long formed a subject of inquiry and conjecture. The change, though sufficient for the purpose, is so minute as to elude ordinary observation. Some very late discoveries, deduced from a laborious and most accurate inspection of the structure and operation of the organ, seem at length to have ascertained the mechanical alteration which the parts of the eye undergo. It is found, that by the action of certain muscles * called the straight mus-

sighted persons, from too great convexity of the cornea or lens. The former is the defect of long-sighted persons, in whom there is an opposite conformation of those parts.

* Fig. 7. There are four *straight* muscles *a, a, a, a,* belonging to the globe of the eye. These muscles resemble each other, each arising from the bottom of the orbit, where they surround *c*, the optic nerve; they are strong and fleshy, and are inserted by broad thin tendons at the fore part of the globe of the eye, into the tunica

cles, and which action is the most advantageous that could be imagined for the purpose,—it is found, I say, that whenever the eye is directed to a near object, three changes are produced in it at the same time, all severally contributing to the adjustment required. The cornea, or outermost coat of the eye, is rendered more round and prominent; the crystalline lens underneath is pushed forward; and the axis of vision, as the depth of the eye is called, is elongated. These changes in the eye vary its power over the rays of light in such a manner and degree as to produce exactly the effect which is wanted, viz. the formation of an image *upon the retina*, whether the rays come to the eye in a state of divergency, which is the case when the object is near to the eye, or come parallel to one another, which is the case when the object is placed at a distance. Can any thing be more decisive of contrivance than this is? The most secret laws of optics must have been known to the author of a structure endowed with such a capacity of change. It is as though an optician, when he had a nearer object to view, should *rectify* his instrument by putting in another glass, at

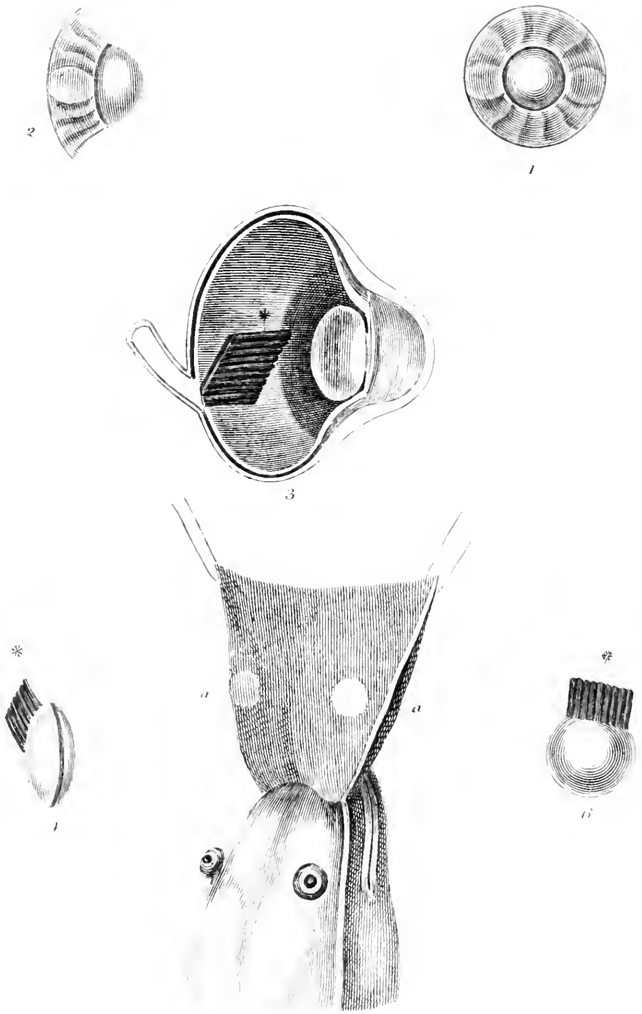
sclerotica. The internal changes of the eye are chiefly accomplished by the pressure of these muscles on the ball. The more obvious use of the straight muscles, and the action which is assigned to them by anatomical writers, is, to turn the eye in different directions: hence they are severally named—levator oculi, depressor oculi, adductor oculi, and abductor oculi.

the same time drawing out also his tube to a different length.

Observe a new-born child first lifting up its eyelids. What does the opening of the curtain discover? The anterior part of two pellucid globes, which, when they come to be examined, are found to be constructed upon strict optical principles; the self-same principles upon which we ourselves construct optical instruments. We find them perfect for the purpose of forming an image by refraction; composed of parts executing different offices: one part having fufilled its office upon the pencil of light, delivering it over to the action of another part; that to a third, and so onward: the progressive action depending for its success upon the nicest and minutest adjustment of the parts concerned; yet, these parts so in fact adjusted as to produce, not by a simple action or effect, but by a combination of actions and effects, the result which is ultimately wanted. And forasmuch as this organ would have to operate under different circumstances, with strong degrees of light and with weak degrees, upon near objects, and upon remote ones, and these differences demanded, according to the laws by which the transmission of light is regulated, a corresponding diversity of structure; that the aperture, for example, through which the light passes, should be larger or less; the lenses rounder or flatter, or that their distance from the tablet, upon which the picture is delineated, should be shortened or lengthened; this, I say, being the case and the difficulty to which the eye was to be adapted, we find its several parts capable of being occasionally changed, and a most artificial apparatus provided to produce that change. This is far beyond the common regulator of a watch, which requires the touch of a foreign hand to set it; but it is not altogether unlike Harrison's contrivance for making a watch regulate itself, by inserting within it a machinery, which, by the artful use of the different expansion of metals, preserves the equability of the motion under all the various temperatures of heat and cold in which the instrument may happen to be placed. The ingenuity of this last contrivance has been justly praised. Shall, therefore, a structure which differs from it, chiefly by surpassing it, be accounted no contrivance at all? or, if it be a contrivance, that it is without a contriver?

But this, though much, is not the whole; by different species of animals the faculty we are describing is possessed, in degrees suited to the different range of vision which their mode of life, and of procuring their food, requires. *Birds*, for instance, in general, procure their food by means of their beak: and, the distance between the eye and the point of the beak being small, it becomes necessary that they should have the power of seeing very near objects distinctly. On the other hand, from being often elevated much above the ground,

TAB. III.



living in air, and moving through it with great velocity, they require, for their safety, as well as for assisting them in descrying their prey, a power of seeing at a great distance; a power of which, in birds of rapine, surprising examples are given. The fact accordingly is, that two peculiarities are found in the eyes of birds, both tending to *facilitate* the change upon which the adjustment of the eye to different distances depends. The one is a bony, yet in most species, a flexible rim or hoop,* surrounding the broadest part of the eye; which, confining the action of the muscles † to that part, increases the effect of their lateral pressure upon

* Tab. III. Fig. 1, 2. *The flexible rim, or hoop*, consists of bony plates, which in all birds occupy the front of the sclerotic; lying close together and overlapping each other, These bony plates in general form a slightly convex ring, Fig. 1, but in the *accipitres* they form a concave ring, as in Fig. 2, the bony rim of a hawk. It is a principle in optics, that the rays of light, passing through a lens, will be refracted to a point or focus beyond the lens, and this focus will be less distant in proportion as the lens approaches to a sphere in shape. This principle is very naturally applied to the explanation of the use of this apparatus. These scales partly lying over each other, so as to allow of motion, will, on the contraction of the straight muscles inserted into and covering them, move over each other, and diminish the circle of the sclerotica; and thus the cornea, which is immediately within the circle made by these scales, must be pressed forwards and rendered more convex, from the focus of the eye becoming altered, by its axis being elongated. This consequent convexity of the cornea renders small objects near the animal very distinct. Without this structure a bird would be continually liable to dash itself against trees when flying in a thick forest, and would be unable to see the minute objects on which it sometimes feeds.

† These muscles resemble the straight muscles of the human eye, and the eyes of all animals possess similar moving powers.

the orb, by which pressure its axis is elongated for the purpose of looking at very near objects. The other is an additional muscle, called the marsupium,* to draw, on occasion, the crystalline lens *back*, and to fit the same eye for the viewing of very distant objects. By these means, the eyes of birds can pass from one extreme to another of their scale of adjustment, with more ease and readiness than the eyes of other animals.

The eyes of *fishes* also, compared with those of terrestrial animals, exhibit certain distinctions of structure adapted to their state and element. We have already observed upon the figure of the crystalline compensating by its roundness the density of the medium through which their light passes. To which we have to add, that the eyes of fishes, in their natural and indolent state, appear to be adjusted to near objects, in this respect differing from the human eye, as well as those of quadrupeds and birds. The ordinary shape of the fish's eye being

* The *marsupium* arises from the back of the eye; proceeding apparently through a slit in the retina, it passes obliquely into the vitreous humour, and terminates in that part, as in the eagle. Fig. 3. a section of the eye of the falco chrysaëtos. In some species it reaches the lens, and is attached to it, as in Fig. 4. 6. In the plate the marsupium is marked with an *. We have now seen the form, but it is very much questioned whether it has the office here assigned to it: no muscular fibres are apparent, and its oblique situation seems unfavourable to the conjecture of its having muscular power. The marsupium has a structure resembling the choroid coat, is covered by the same black pigment, and answers the same purpose; that of absorbing the rays of light when too strong, and intercepting some of the rays in their course to the retina.

in a much higher degree convex than that of land animals, a corresponding difference attends its muscular conformation, viz. that it is throughout calculated for *flattening* the eye.

The *iris* also in the eyes of fishes does not admit of contraction. This is a great difference, of which the probable reason is, that the diminished light in water is never too strong for the retina.

In the *eel*, which has to work its head through sand and gravel, the roughest and harshest substances, there is placed before the eye, and at some distance from it, a transparent, horny, convex case or covering, which, without obstructing the sight, defends the organ.* To such an animal, could any thing be more wanted, or more useful?

Thus, in comparing the eyes of different kinds of animals, we see, in their resemblances and distinctions, one general plan laid down, and that plan varied with the varying exigencies to which it is to be applied.

There is one property, however, common I believe to all eyes, at least to all which have been examined, namely, that the optic nerve enters the bottom of the eye, not in the centre or middle, but a little on one side: not in the point where the

* Fig. 5. The skin of the head of an *eel* is represented turned back: and as the *transparent horny covering* of the eye *a*, *a*, is a cuticular covering, it is separated with it. Other fish, have a similar, insensible, dense, and thick adnata, which is designed to protect the eye; and it seems especially necessary as fish have no eye-lids.

axis of the eye meets the retina, but between that point and the nose. The difference which this makes is, that no part of an object is unperceived by both eyes at the same time.

In considering vision as achieved by the means of an image formed at the bottom of the eye, we can never reflect without wonder upon the smallness, yet correctness of the picture, the subtilty of the touch, the fineness of the lines. A landscape of five or six square leagues is brought into a space of half an inch diameter; yet the multitude of objects which it contains, are all preserved; are all discriminated in their magnitudes, positions, figures, colours. The prospect from Hampstead-hill is compressed into the compass of a sixpence, yet circumstantially represented. A stage-coach, travelling at its ordinary speed for half an hour, passes, in the eye, only over one-twelfth of an inch, yet is this change of place in the image distinctly perceived throughout its whole progress; for it is only by means of that perception that the motion of the coach itself is made sensible to the eye. If any thing can abate our admiration of the smallness of the visual tablet compared with the extent of vision, it is a reflection, which the view of nature leads us, every hour, to make, viz. that, in the hands of the Creator, great and little are nothing.*

* The magnitude of the image formed on the retina, is proportional to the angle which the two extremities of the object viewed

Sturmius held, that the examination of the eye was a cure for atheism. Besides that conformity to optical principles which its internal constitution displays, and which alone amounts to a manifestation of intelligence having been exerted in the structure; besides this, which forms, no doubt, the leading character of the organ, there is to be seen, in every thing belonging to it and about it, an extraordinary degree of care, an anxiety for its preservation, due, if we may so speak, to its value and its tenderness. It is lodged in a strong, deep, bony socket, composed by the junction of seven different bones,* hollowed out at their orbitary processes. In some few species, as that of the coatimondi,† the orbit is not bony throughout; but whenever this is the case, the upper, which is the deficient part, is supplied by a cartilaginous ligament; a substitution which shews the same care. Within this socket it is imbedded in fat, of all animal substances the best adapted both to its repose and motion. It is sheltered by the eye-brows; an arch of hair, which, like a thatched penthouse, prevents the sweat and moisture of the forehead from running down into it.

But it is still better protected by its *lid*. Of

subtend with the centre of the eye. Hence the more remote the object, the smaller the image.

* The frontal, maxillary, malar, lachrymal, ethmoïd, palatine, and sphenoïd bones.

† Mem. R. Ac. Paris. p. 117.

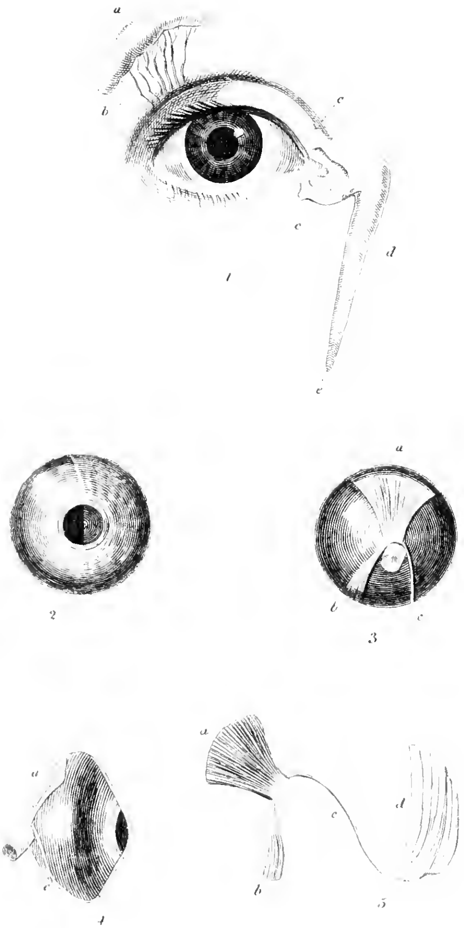
the superficial parts of the animal frame, I know none which, in its office and structure, is more deserving of attention than the eyelid. It defends the eye; it wipes it; it closes it in sleep.* Are there, in any work of art whatever, purposes more evident than those which this organ fulfils? Or an apparatus for executing those purposes more intelligible, more appropriate, or more mechanical? If it be overlooked by the observer of nature, it can only be because it is obvious and familiar. This is a tendency to be guarded against. We pass by the plainest instances, whilst we are exploring those which are rare and curious; by which conduct of the understanding, we sometimes neglect the strongest observations, being taken up with others, which, though more recondite and scientific, are, as solid arguments, entitled to much less consideration.

In order to keep the eye moist and clean, (which qualities are necessary to its brightness and its use,) a wash is constantly supplied by a secretion for the purpose; and the superfluous brine is conveyed to the nose through a perforation in the bone as large as a goose-quill.† When once the fluid has

* The muscles which accomplish these actions are seen in Tab. XIV. Fig. 1, 2. The eyelids also moderate the force of a too brilliant light, and exclude, by a partial closure, that excess of it which would offend the eye. The eyelashes have a similar office, that of regulating the quantity of light: and it is believed, that they protect the eye from the small particles of dust that float in the air.

† Tab. IV. Fig. 1. *a*, is the organ which supplies this fluid,

TAB. IV



entered the nose, it spreads itself upon the inside of the nostril, and is evaporated by the current of warm air, which, in the course of respiration, is continually passing over it. Can any pipe or outlet, for carrying off the waste liquor from a dye-house or a distillery, be more mechanical than this is? It is easily perceived, that the eye must want moisture; but could the want of the eye generate the gland which produces the tear, or bore the hole by which it is discharged,—a hole through a bone?

It is observable, that this provision is not found in fishes,—the element in which they live supplying a constant lotion to the eye.

It were, however, injustice to dismiss the eye as a piece of mechanism, without noticing that most exquisite of all contrivances, the *nictitating membrane*,* which is found in the eyes of birds and of many quadrupeds. Its use is to sweep the eye,

called the *lachrymal gland*, it is situated at the outer and upper part of the orbit of the eye. This is the gland which secretes or separates the tears from the blood. There are five or six ducts or tubes, *b*, which convey this fluid to the globe of the eye, for the purpose of keeping it moist, and for facilitating its movements; the motion of the eyelid diffuses the tears, and *c*, *c*, the *puncta lachrymalia*, take up the superfluous moisture, which passes through *d*, the *lachrymal sac and duct* into the nostril at *e*.

* Fig. 2. The *nictitating membrane*, or third eyelid, is a thin semi-transparent fold of the conjunctive, which, in a state of rest, lies in the inner corner of the eye, with its loose edge nearly vertical, but can be drawn out so as to cover the whole front of the globe. In this figure it is represented in the act of being drawn over the eye. By means of this membrane, according to Cuvier, the eagle is enabled to look at the sun.

which it does in an instant, to spread over it the lachrymal humour; to defend it also from sudden injuries: yet not totally, when drawn upon the pupil, to shut out the light. The commodiousness with which it lies folded up in the inner corner of the eye, ready for use and action, and the quickness with which it executes its purpose, are properties known and obvious to every observer: but what is equally admirable, though not quite so obvious, is the combination of two kinds of substance, muscular and elastic, and of two different kinds of action, by which the motion of this membrane is performed. It is not, as in ordinary cases, by the action of two antagonist muscles, one pulling forward and the other backward, that a reciprocal change is effected; but it is thus: the membrane itself is an elastic substance, capable of being drawn out by force like a piece of elastic gum, and by its own elasticity returning, when the force is removed, to its former position. Such being its nature, in order to fit it up for its office, it is connected by a tendon or thread with a muscle in the back part of the eye:* this tendon

* Fig. 3. These two very singular muscles are attached to the back of the sclerotica; one of them, which from its shape is called *quadratus*, *a*, has its origin from the upper and back part of the sclerotica; its fibres descend towards the optic nerve, and terminate in a curved margin with a cylindrical canal in it. The other muscle, *b*, which is called *pyramidalis*, arises from the lower and back part of the sclerotica. It has a long tendinous chord, *c*, which passes through the canal of the quadratus, *a*, as a pulley, and, hav-

or thread, though strong, is so fine as not to obstruct the sight, even when it passes across it; and the muscle itself, being placed in the *back* part of the eye, derives from its situation the advantage, not only of being secure, but of being out of the way; which it would hardly have been in any position that could be assigned to it in the anterior part of the orb, where its function lies. When the muscle behind the eye contracts, the membrane, by means of the communicating thread, is instantly drawn over the fore-part of it. When the muscular contraction (which is a positive, and, most probably, a voluntary effort) ceases to be exerted, the elasticity alone of the membrane brings it back again to its position.* Does not this, if any thing can do it, bespeak an artist, master of his work, acquainted with his materials? "Of a thousand other things," say the French academicians, "we perceive not the contrivance, because we understand them only by the effects, of which we know not the causes: but we here treat of a machine, all the parts whereof are visible; and which need only be looked upon to discover the reasons of its motion and action."†

ing arrived at the lower and exterior part of the eye-ball, is inserted into the loose edge of the nictitating membrane. This description refers also to Fig. 4. a profile of the eye, and Fig. 5. the membrane and its muscles detached from the eye.

* Phil. Trans. 1796.

† Memoirs for a Natural History of Animals, by the Royal Academy of Sciences at Paris, done into English by order of the Royal Society, 1701, page 249.

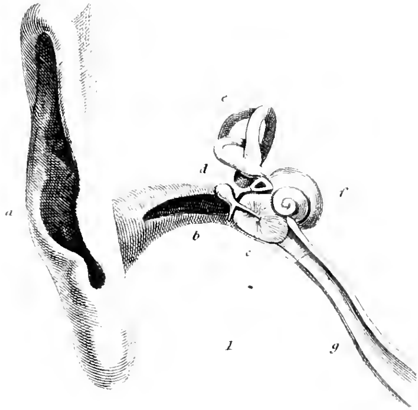
In the configuration of the muscle which, though placed behind the eye, draws the nictitating membrane over the eye, there is, what the authors just now quoted deservedly call a marvellous mechanism. I suppose this structure to be found in other animals; but, in the memoirs from which this account is taken, it is anatomically demonstrated only in the cassowary. The muscle is *passed through a loop formed by another muscle;* and is there inflected, as if it were round a pulley. This is a peculiarity; and observe the advantage of it. A single muscle with a straight tendon, which is the common muscular form, would have been sufficient, if it had had power to draw far enough. But the contraction, necessary to draw the membrane over the whole eye, required a longer muscle than could lie straight at the bottom of the eye. Therefore, in order to have a greater length in a less compass, the cord of the main muscle makes an angle. This, so far, answers the end; but, still further, it makes an angle, not round a fixed pivot, but round a loop formed by another muscle; which second muscle, whenever it contracts, of course twitches the first muscle at the point of inflection, and thereby assists the action designed by both.

One question may possibly have dwelt in the reader's mind during the perusal of these observations, namely, Why should not the Deity have given to the animal the faculty of vision *at once?* Why this circuitous perception; the ministry of so many means; an element provided for the purpose; reflected from opaque substances, refracted through transparent ones; and both according to precise laws; then, a complex organ, an intricate and artificial apparatus, in order, by the operation of this element, and in conformity with the restrictions of these laws, to produce an image upon a membrane communicating with the brain? Wherefore all this? Why make the difficulty in order to surmount it? If to perceive objects by some other mode than that of touch, or objects which lay out of the reach of that sense, were the thing proposed; could not a simple volition of the Creator have communicated the capacity? Why resort to contrivance, where power is omnipotent? Contrivance, by its very definition and nature, is the refuge of imperfection. To have recourse to expedients implies difficulty, impediment, restraint, defect of power. This question belongs to the other senses, as well as to sight; to the general functions of animal life, as nutrition, secretion, respiration; to the economy of vegetables; and indeed to almost all the operations of nature. The question, therefore, is of very wide extent; and amongst other answers which may be given to it, besides reason of which probably we are ignorant, one answer, is this: it is only by the display of contrivance, that the existence, the agency, the wisdom of the Deity, *could* be testified to his rational creatures. This is the scale by which we ascend to all the knowledge of our Creator which we possess, so far as it depends upon the phænomena, or the works of nature. Take away this, and you take away from us every subject of observation, and ground of reasoning; I mean as our rational faculties are formed at present. Whatever is done, God could have done without the intervention of instruments or means; but it is in the construction of instruments, in the choice and adaptation of means, that a creative intelligence is seen. It is this which constitutes the order and beauty of the universe. God, therefore, has been pleased to prescribe limits to his own power, and to work his ends within those limits. The general laws of matter have perhaps the nature of these limits; its inertia, its reaction; the laws which govern the communication of motion, the refraction and reflection of light, the constitution of fluids non-elastic and elastic, the transmission of sound through the latter; the laws of magnetism, of electricity; and probably others, yet undiscovered. These are general laws; and when a particular purpose is to be effected, it is not by making a new law, nor by the suspension of the old ones, nor by making them wind, and bend, and yield to the occasion; (for nature with great steadiness adheres to and supports them,) but it is, as we have seen in the eye, by the interposition of an apparatus, corresponding with these laws, and suited to the exigency which results from them, that the purpose is at length attained. As we have said, therefore, God prescribes limits to his power, that he may let in the exercise, and thereby exhibit demonstrations of his wisdom. For then, *i. e.* such laws and limitations being laid down, it is as though one Being should have fixed certain rules; and, if we may so speak, provided certain materials; and, afterwards, have committed to another Being, out of these materials, and in subordination to these rules, the task of drawing forth a creation; a supposition which evidently leaves room, and induces indeed a necessity for contrivance. Nay, there may be many such agents, and many ranks of these. We do not advance this as a doctrine either of philosophy or of religion; but we say that the subject may safely be represented under this view, because the Deity, acting himself by general laws, will have the same consequences upon our reasoning, as if he had prescribed these laws to another. It has been said, that the problem of creation was, "attraction and matter being given, to make a world out of them:" and, as above explained, this statement perhaps does not convey a false idea.

We have made choice of the eye as an instance upon which to rest the argument of this chapter. Some single example was to be proposed; and the eye offered itself under the advantage of admitting of a strict comparison with optical instruments. The ear, it is probable, is no less artificially and mechanically adapted to its office than the eye. But we know less about it: we do not so well understand the action, the use, or the mutual dependency of its internal parts. Its general form, however, both external and internal, is sufficient to shew that it is an instrument adapted to the reception of *sound;* that is to say, already knowing that sound consists in pulses of the air, we perceive in the structure of the ear, a suitableness to receive impressions from this species of action, and to propagate these impressions to the brain. For of what does this structure consist? An external ear (the concha,*) calculated, like an ear-trumpet, to catch and collect the pulses of which we have spoken; in large quadrupeds, turning to the sound, and possessing a configuration, as well as motion, evidently fitted for the office: of a tube which leads into the head, lying at the root of this outward ear, the folds and sinuses therefore tending and conducting the air towards it: of a thin membrane, like the pelt of a drum, stretched across this passage upon a bony rim: of a chain of moveable, and infinitely curious bones, forming a communi-

* Tab. V. Fig. 1. The organ of hearing, *a*, the *external ear;* *b*, the *meatus auditorius externus*, or outward passage of the ear; leading to *c*, the *membrana tympani*, or drum; *d*, the *ossicula auditus*, or little bones of the ear; *e*, the *semicircular canals; f*, the *cochlea; g*, a section of the *eustachian tube*, which extends from the cavity of the tympanum, to the back of the mouth or fauces.

TAB V



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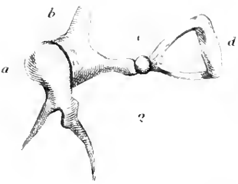

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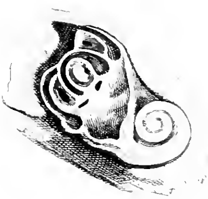

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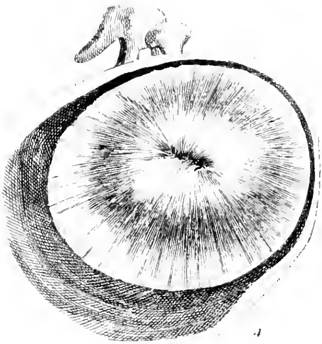

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cation, and the only communication that can be observed, between the membrane last mentioned and the interior channels and recesses of the skull: of cavities, similar in shape and form to wind instruments of music, being spiral or portions of circles: of the eustachian tube like the hole in a drum, to let the air pass freely into and out of the barrel of the ear, as the covering membrane vibrates, or as the temperature may be altered: the whole labyrinth * hewn out of a rock ;† that is, wrought into the substance of the hardest bone of the body. This assemblage of connected parts constitutes together an apparatus, plainly enough relative to the transmission of sound, or of the impulses received from sound, and only to be lamented in not being better understood.

The communication within, formed by the small bones of the ear,‡ is, to look upon, more like what we are accustomed to call machinery, than any thing I am acquainted with in animal bodies. It seems evidently designed to continue towards the sensorium, the tremulous motions which are ex-

* Fig. 3. *The labyrinth*, so named from the intricacy of the cavities contained within it. It consists of the *vestibule, semicircular canals*, and *cochlea*, so named from its resemblance to the windings of a snail shell, and is best explained by the plate. Fig. 1 and 3.

† Hence called the *petrous* part of the temporal bone.

‡ Fig. 2. The bones of the ear magnified, *a*, the *malleus*, or hammer, connected by a process to the tympanum: the round head is lodged in the body of *b*, the *incus* or anvil, and the incus is united to *c*, the *os orbiculare*, or round bone, and this to *d*, the *stapes*, or

cited in the membrane of the tympanum, or what is better known by the name of the "drum of the ear." The compages of bones consists of four, which are so disposed, and so hinge upon one another, as that if the membrane, the drum of the ear, vibrate, all the four are put in motion together; and, by the result of their action, work the base of that which is the last in the series, upon an aperture * which it closes, and upon which it plays, and which aperture opens into the tortuous canals, that lead to the brain.† This last bone of the four is called the *stapes*. The office of the drum of the ear is to spread out an extended surface, capable of receiving the impressions of sound, and of being put by them into a state of vibration. The office of the stapes is to repeat these vibrations. It is a repeating frigate, stationed more within the line. From which account of its action may be understood, how the sensation of sound will be excited by any thing which communicates

the stirrup. These bones are named from their shape, and the names assist in conveying an idea of their form. They are united by ligaments, and form an uninterrupted chain to transmit the vibrations of the atmosphere.

* The *fenestra ovalis*.

† The description of the organ of hearing is so accurate as scarcely to require further explanation, only observing, that sounds striking against the membrana tympani, are propagated by the intervention of the four little bones, to the *water* contained within the cavities of the labyrinth; and by means of this water the impression is conveyed to the extremities of the *auditory nerve*, and finally to the brain. See Scarpa de aure humana, also Saunders on the ear.

a vibratory motion to the stapes, though not, as in all ordinary cases, through the intervention of the membrana tympani. This is done by solid bodies applied to the bones of the skull, as by a metal bar holden at one end between the teeth, and touching at the other end a tremulous body. It likewise appears to be done, in a considerable degree, by the air itself, even when this membrane, the drum of the ear, is greatly damaged. Either in the natural or preternatural state of the organ, the use of the chain of bones is to propagate the impulse in a direction towards the brain, and to propagate it with the advantage of a lever; which advantage consists in increasing the force and strength of the vibration, and at the same time diminishing the space through which it oscillates; both of which changes may augment or facilitate the still deeper action of the auditory nerves.

The benefit of the eustachian tube to the organ, may be made out upon known pneumatic principles. Behind the drum of the ear is a second cavity, or barrel, called the tympanum. The eustachian tube is a slender pipe, but sufficient for the passage of air, leading from this cavity into the back part of the mouth. Now, it would not have done to have had a vacuum in this cavity; for, in that case, the pressure of the atmosphere from without would have burst the membrane which covered it. Nor would it have done to have filled the cavity with lymph or any other secretion; which would necessarily have obstructed both the vibration of the membrane and the play of the small bones. Nor, lastly, would it have done to have occupied the space with confined air, because the expansion of that air by heat, or its contraction by cold, would have distended or relaxed the covering membrane, in a degree inconsistent with the purpose which it was assigned to execute. The only remaining expedient, and that for which the eustachian tube serves, is to open to this cavity a communication with the external air. In one word; it exactly answers the purpose of the hole in a drum.

The membrana tympani itself, likewise, deserves all the examination which can be made of it. It is not found in the ears of fishes; * which furnishes an additional proof of what indeed is indicated by every thing about it, that it is appropriated to the action of air, or of an elastic medium. It bears an obvious resemblance to the pelt or head of a drum, from which it takes its name. It resembles also a drum-head in this principal property, that its use depends upon its tension. *Tension* is the

* In fishes the organ of hearing is simple, consisting of a cavity distended with fluid, and containing a bone, or concrete substances; and there are semicircular canals, similar in shape and situation to those found in the mammalia: the auditory nerve being distributed in a beautiful net-work upon the bony concretions, and within the canals. Not only is the impression of sound transmitted through the bones of the head, by the water, but is conveyed by the same medium to the bottom of the ear; hence it is evident, that fish require no external ear, tympanum, or eustachian tube.

state essential to it. Now we know that, in a drum, the pelt is carried over a hoop, and braced, as occasion requires, by the means of strings attached to its circumference. In the membrane of the ear, the same purpose is provided for, more simply, but not less mechanically, nor less successfully, by a different expedient, viz. by the end of a bone (the handle of the malleus) pressing upon its centre. It is only in very large animals that the texture of this membrane can be discerned. In the Philosophical Transactions for the year 1800, (vol. i.) Sir Everard Home has given some curious observations upon the ear, and the drum of the ear of an *elephant*.* He discovered in it what he calls a radiated muscle, that is, straight muscular fibres, passing along the membrane from the circumference to the centre; from the bony rim which surrounds it towards the handle of the malleus to which the central part is attached. This muscle he supposed to be designed to bring the membrane into unison with different sounds: but then he also discovered, that this muscle itself cannot act, unless the membrane be drawn to a stretch, and kept in a due state of tightness, by what may be called a foreign force, viz. the action of the muscles of the malleus. Supposing his explanation of the use of the parts to be just, our author is well founded in the reflection

* Fig. 4. The tympanum of the elephant, of its natural size, shewing its radiated fibres, supposed to be muscular.

which he makes upon it. "That this mode of adapting the ear to different sounds, is one of the most beautiful applications of muscles in the body; *the mechanism is so simple, and the variety of effects so great.**"

In another volume of the Transactions above referred to, and of the same year, two most curious cases are related, of persons who retained the sense of hearing, not in a perfect, but in a very considerable degree, notwithstanding the almost total

* As the ear of man and fish has been described, it may not be improper in this place to state, that the other classes of animals are no less admirably provided with an ear, adapted to their peculiar habits and economy.

In amphibious animals the organ of hearing has an intermediate structure; in some species of this class, the ear resembling fish, in others it resembles the formation of terrestrial animals.

There is an important addition to this organ in birds: viz. a cochlea and proper tympanum.

In quadrupeds we find a more complicated organization; to collect the vibrations of sound, they have an external ear, and all those parts, though of a different figure, which belong to the human ear.

The capacity for enjoyment of music is mental, but all the curious varieties of sound, which are the source of this enjoyment, are communicated by the mechanical provisions of the ear. We are astonished at the varieties of sensation; the ear is capable of perceiving four or five hundred variations of tone in sound. "Hence we may conceive a prodigious variety in the same tone, arising from irregularities of it occasioned by constitution, figure, situation or manner of striking the sonorous body; from the constitution of the elastic medium, or its being disturbed by other motions; and from the constitution of the ear itself, upon which the impression is made. A flute, a violin, a hautboy, a French horn, may all sound the same tone, and be easily distinguishable. Nay, if twenty human voices sound the same note, and with equal strength, there will be some difference." Reid's Enquiry, page 98.

loss of the membrane we have been describing. In one of these cases, the use here assigned to that membrane, of modifying the impressions of sound by change of tension, was attempted to be supplied by straining the muscles of the outward ear. "The external ear," we are told, "had acquired a distinct motion upward and backward, which was observable whenever the patient listened to any thing which he did not distinctly hear; when he was addressed in a whisper, the ear was seen immediately to move; when the tone of voice was louder, it then remained altogether motionless."

It appears probable, from both these cases, that a collateral, if not principal, use of the membrane, is to cover and protect the barrel of the ear which lies behind it. Both the patients suffered from cold: one, "a great increase of deafness from catching cold;" the other, "very considerable pain from exposure to a stream of cold air." Bad effects therefore followed from this cavity being left open to the external air; yet had the Author of nature shut it up by any other cover, than what was capable, by its texture, of receiving vibrations from sound, and, by its connexion with the interior parts, of transmitting those vibrations to the brain, the use of the organ, so far as we can judge, must have been entirely obstructed.

CHAPTER IV.

OF THE SUCCESSION OF PLANTS AND ANIMALS.

THE *generation* of the animal no more accounts for the contrivance of the eye or ear, than, upon the supposition stated in a preceding chapter, the production of a watch by the motion and mechanism of a former watch, would account for the skill and intention evidenced in the watch so produced; than it would account for the disposition of the wheels, the catching of their teeth, the relation of the several parts of the works to one another, and to their common end; for the suitableness of their forms and places to their offices, for their connexion, their operation, and the useful result of that operation. I do insist most strenuously upon the correctness of this comparison; that it holds as to every mode of specific propagation; and that whatever was true of the watch, under the hypothesis above-mentioned, is true of plants and animals.

I. To begin with the fructification of plants. Can it be doubted but that the seed contains a particular organization? Whether a latent plantule with the means of temporary nutrition, or whatever else it be, it encloses an organization suited to the germination of a new plant. Has the plant which produced the seed any thing more to do with that organization, than the watch would have had to do with the structure of the watch which was produced in the course of its mechanical movement; I mean, has it any thing at all to do with the *contrivance?* The maker and contriver of one watch, when he inserted within it a mechanism suited to the production of another watch, was, in truth, the maker and contriver of that other watch. All the properties of the new watch were to be referred to his agency: the design manifested in it, to his intention: the art, to him as the artist: the collocation of each part to his placing: the action, effect, and use, to his counsel, intelligence, and workmanship. In producing it by the intervention of a former watch, he was only working by one set of tools instead of another. So it is with the plant, and the seed produced by it. Can any distinction be assigned between the two cases; between the producing watch, and the producing plant; both passive, unconscious substances; both by the organization which was given to them, producing their like, without understanding or design; both, that is, instruments?

II. From plants we may proceed to oviparous animals; from seeds to eggs. Now, I say, that the bird has the same concern in the formation of the egg which she lays, as the plant has in that of the seed which it drops; and no other, nor greater.

The internal constitution of the egg is as much a secret to the hen, as if the hen were inanimate. Her will cannot alter it, or change a single feather of the chick. She can neither foresee nor determine of which sex her brood shall be, or how many of either; yet the thing produced shall be, from the first, very different in its make, according to the sex which it bears. So far, therefore, from adapting the means, she is not beforehand apprised of the effect. If there be concealed within that smooth shell a provision and a preparation for the production and nourishment of a new animal, they are not of her providing or preparing: if there be contrivance, it is none of hers. Although, therefore, there be the difference of life and perceptivity between the animal and the plant, it is a difference which enters not into the account. It is a foreign circumstance. It is a difference of properties not employed. The animal function and the vegetable function are alike destitute of any design which can operate upon the form of the thing produced. The plant has no design in producing the seed, no comprehension of the nature or use of what it produces; the bird, with respect to its egg, is not above the plant with respect to its seed. Neither the one nor the other bears that sort of relation to what proceeds from them, which a joiner does to the chair which he makes. Now a cause, which bears *this* relation to the effect, is what we want, in order to account for the suitableness of means to an end, the fitness and fitting of one thing to another; and this cause the parent plant or animal does not supply.

It is farther observable concerning the propagation of plants and animals, that the apparatus employed exhibits no resemblance to the thing produced; in this respect holding an analogy with instruments and tools of art. The filaments, antheræ, and stigmata of flowers, bear no more resemblance to the young plant, or even to the seed, which is formed by their intervention, than a chisel or a plane does to a table or chair. What then are the filaments, antheræ, and stigmata of plants, but instruments strictly so called?

III. We may advance from animals which bring forth eggs, to animals which bring forth their young alive: and of this latter class, from the lowest to the highest; from irrational to rational life, from brutes to the human species: without perceiving, as we proceed, any alteration whatever in the terms of the comparison. The rational animal does not produce its offspring with more certainty or success than the irrational animal; a man than a quadruped, a quadruped than a bird; nor (for we may follow the gradation through its whole scale) a bird than a plant; nor a plant than a watch, a piece of dead mechanism, would do, upon the supposition which has already so often been repeated. Rationality therefore has nothing to do in the business. If an account must be given of the contrivance which we observe; if it be demanded, whence arose either the contrivance by which the young animal is produced, or the contrivance manifested in the young animal itself, it is not from the reason of the parent that any such account can be drawn. He is the cause of his offspring, in the same sense as that in which a gardener is the cause of the tulip which grows upon his parterre, and in no other. We admire the flower; we examine the plant; we perceive the conduciveness of many of its parts to their end and office; we observe a provision for its nourishment, growth, protection and fecundity; but we never think of the gardener, in all this. We attribute nothing of this to his agency; yet it may still be true, that without the gardener we should not have had the tulip: just so it is with the succession of animals even of the highest order. For the contrivance discovered in the structure of the thing produced, we want a contriver. The parent is not that contriver. His consciousness decides that question. He is in total ignorance why that which is produced took its present form rather than any other. It is for him only to be astonished by the effect. We can no more look therefore to the intelligence of the parent animal for what we are in search of, a cause of relation, and of subserviency of parts to their use, which relation and subserviency we see in the procreated body, than we can refer the internal conformation of an acorn to the intelligence of the oak from which it dropped, or the structure of the watch, to the intelligence of the watch which produced it ; there being no difference, as far as argument is concerned, between an intelligence which is not exerted, and an intelligence which does not exist.

CHAPTER V.

APPLICATION OF THE ARGUMENT CONTINUED.

EVERY observation which was made in our first chapter, concerning the watch, may be repeated with strict propriety concerning the eye ; concerning animals ; concerning plants ; concerning, indeed, all the organized parts of the works of nature. As,

I. When we are inquiring simply after the *existence* of an intelligent Creator, imperfection, inaccuracy, liability to disorder, occasional irregularities, may subsist in a considerable degree, without inducing any doubt into the question : just as a watch may frequently go wrong, seldom perhaps exactly right, may be faulty in some parts, defective in some, without the smallest ground of suspicion from thence arising that it was not a watch ; not made ; or not made for the purpose ascribed to it. When faults are pointed out, and when a question is started concerning the skill of the artist, or dexterity with which the work is executed, then indeed, in order to defend these qualities from accusation, we must be able either to expose some intractableness and imperfection in the materials, or point out some invincible difficulty in the execution, into which imperfection and difficulty the matter of complaint may be resolved; or if we cannot do this, we must adduce such specimens of consummate art and contrivance, proceeding from the same hand, as may convince the inquirer of the existence, in the case before him, of impediments like those which we have mentioned, although, what from the nature of the case is very likely to happen, they be unknown and unperceived by him. This we must do in order to vindicate the artist's skill, or, at least, the perfection of it; as we must also judge of his intention, and of the provision employed in fulfilling that intention, not from an instance in which they fail, but from the great plurality of instances in which they succeed. But, after all, these are different questions from the question of the artist's existence; or, which is the same, whether the thing before us be the work of art or not: and the questions ought always to be kept separate in the mind. So likewise it is in the works of nature. Irregularities and imperfections are of little or no weight in the consideration, when that consideration relates simply to the existence of a Creator. When the argument respects his attributes, they are of weight; but are then to be taken in conjunction (the attention is not to rest upon them, but they are to be taken in conjunction) with the unexceptionable evidences which we possess, of skill, power, and benevolence, displayed in other instances; which evidences may, in strength, number, and variety, be such, and may so overpower apparent blemishes, as to induce us, upon the most reasonable ground, to believe, that these last ought to be referred to some cause, though we be ignorant of it, other than defect of knowledge or of benevolence in the author.

II. There may be also parts of plants and animals, as there were supposed to be of the watch, of which, in some instances, the operation, in others, the use, is unknown. These form different causes; for the operation may be unknown, yet the use be certain. Thus it is with the lungs of animals. It does not, I think, appear, that we are acquainted with the action of the air upon the blood, or in what manner that action is communicated by the lungs;* yet we find that a very short

* More recent discoveries prove that the lungs are the seat of two very different series of phenomena. The phenomena of the first series, which are entirely mechanical, are relative to the rise and fall of the ribs and diaphragm, and to the dilatation and contraction of the air-vessels, and to the entrance and exit of the air as effected by these movements. The phenomena of the second series are purely chemical, and may be referred to that alteration which the blood undergoes in its passage through the lungs during respi-

suspension of their office destroys the life of the animal. In this case, therefore, we may be said to know the use, nay we experience the necessity, of the organ, though we be ignorant of its operation. Nearly the same thing may be observed of what is called the lymphatic system.* We suffer grievous inconveniencies from its disorder, without being informed of the office which it sustains in the economy of our bodies. There may possibly also be some few examples of the second class, in which not only the operation is unknown, but in which experiments may seem to prove that the part is not necessary; or may leave a doubt, how far it is even useful to the plant or animal in which it is found. This is said to be the case with the spleen; which has been extracted from dogs, without any sensible injury to their vital function. Instances of the former kind, namely, in which we cannot explain the operation, may be numerous; for they will be so in proportion to our ignorance. They will be more or fewer to different persons, and in different stages of science. Every im-

ration; by means of which process, the oxygen of the atmosphere being united to the carbon of the venous blood, the compound is carried off during the act of respiration in the form of carbonic acid gas. These two series of phenomena have a mutual dependence on each other: without the mechanical, the chemical change could not be made: without the chemical change the blood would cease to excite the brain, in consequence of which that organ would no longer operate on the moving powers, and every function of animal life would be annihilated.

* See Tab. XIX.

provement of knowledge diminishes their number. There is hardly, perhaps, a year passes that does not, in the works of nature, bring some operation, or some mode of operation, to light, which was before undiscovered,—probably unsuspected. Instances of the second kind, namely, where the part appears to be totally useless, I believe to be extremely rare; compared with the number of those of which the use is evident, they are beneath any assignable proportion; and, perhaps, have never been submitted to a trial and examination sufficiently accurate, long enough continued, or often enough repeated. No accounts which I have seen are satisfactory. The mutilated animal may live and grow fat, (as was the case of the dog deprived of its spleen,) yet may be defective in some other of its functions; which, whether they can all, or in what degree of vigour and perfection, be performed, or how long preserved, without the extirpated organ, does not seem to be ascertained by experiment.* But to this case, even were it

* The *spleen* is that spongy mass of flesh which is known in animals by the name of *milt:* it lies at the right end of the stomach. Paley may allude to the experiments of Professor Coleman, of the Veterinary college, who, to ascertain the use, deprived dogs of the spleen, and the only consequences observed were, that the animals became dull, indolent and fat, and their lives appeared shortened; merely a knowledge of these effects from the removal of the spleen, are insufficient for any one to infer that the spleen is "totally useless."

Magendie made the following experiment:—The abdomen of a dog was opened, and the dimensions of the spleen being taken, a fully made out, may be applied the consideration which we suggested concerning the watch, viz. that these superfluous parts do not negative the reasoning which we instituted concerning those parts which are useful, and of which we know the use; the indication of contrivance, with respect to them, remains as it was before.

III. One atheistic way of replying to our observations upon the works of nature, and to the proofs of a Deity which we think that we perceive in them, is to tell us, that all which we see must necessarily have had some form, and that it might as well be its present form as any other. Let us now apply this answer to the eye, as we did before to the watch. Something or other must have occupied that place in the animal's head; must have filled up, we will say, that socket: we will say also, that it must have been of that sort of substance which we call animal substance, as flesh, bone, membrane, cartilage, &c. But that it should have been an *eye*, knowing as we do what an eye comprehends,—viz. that it should

pint of blood was injected into the veins; the spleen was seen gradually to enlarge to near one half above its former dimensions.

On making the opposite experiment, after having measured the magnitude of the spleen, the animal was bled to fainting, and the spleen was observed sensibly to diminish in bulk as the blood flowed. These experiments are calculated to throw some light on the functions of this singular organ. According to this we may conclude, "that the spleen is a true reservoir with elastic walls which constantly press upon the blood it contains," when required by the wants of the vascular system of the animal.

have consisted, first, of a series of transparent lenses (very different, by the bye, even in their substance, from the opaque materials of which the rest of the body is, in general at least, composed; and with which the whole of its surface, this single portion of it excepted, is covered:) secondly, of a black cloth or canvass (the only membrane of the body which is black *) spread out behind these lenses, so as to receive the image formed by pencils of light transmitted through them; and placed at the precise geometrical distance at which, and at which alone, a distinct image could be formed, namely, at the concourse of the refracted rays: thirdly, of a large nerve communicating between this membrane and the brain; without which, the action of light upon the membrane, however modified by the organ, would be lost to the purposes of sensation:—that this fortunate conformation of parts should have

* This description can apply only to the *choroid* coat: this membrane is of use to vision, principally by the dark matter with which it is impregnated, and which absorbs the light immediately after it has traversed the retina. When the light is within certain limits of intensity, the *retina* receives the impression, is the seat of vision, and is of such a form as to receive the most perfect image on every point of its surface, that the state of each refracted ray will admit; and the varying density of the crystalline lens, renders that state more capable of delineating such a picture, than any other imaginable contrivance could have done.

In Albino men and animals, viz. those in which the iris and choroid are red instead of black, vision is extremely imperfect: during the day they can scarcely see sufficiently to go about; a fact which confirms the opinion we have given of the use of this black membrane.

been the lot, not of one individual out of many thousand individuals, like the great prize in a lottery, or like some singularity in nature, but the happy chance of a whole species; nor of one species out of many thousand species, with which we are acquainted, but of by far the greatest number of all that exist; and that under varieties not casual or capricious, but bearing marks of being suited to their respective exigencies:—that all this should have taken place, merely because something must have occupied those points in every animal's forehead;—or, that all this should be thought to be accounted for, by the short answer, "that whatever was there, must have had some form or other," is too absurd to be made more so by any augmentation. We are not contented with this answer; we find no satisfaction in it, by way of accounting for appearances of organization far short of those of the eye, such as we observe in fossil shells, petrified bones, or other substances which bear the vestiges of animal or vegetable recrements, but which, either in respect of utility, or of the situation in which they are discovered, may seem accidental enough. It is no way of accounting even for these things, to say that the stone, for instance, which is shown to us, (supposing the question to be concerning a petrification,) must have contained some internal conformation or other. Nor does it mend the answer to add, with respect to the singularity of the conformation, that, after the event, it is no longer to be computed what the chances were against it. This is always to be computed, when the question is, whether a useful or imitative conformation be the produce of chance, or not: I desire no greater certainty in reasoning, than that by which chance is excluded from the present disposition of the natural world. Universal experience is against it. What does chance ever do for us? In the human body, for instance, chance, *i. e.* the operation of causes without design, may produce a wen, a wart, a mole, a pimple, but never an eye. Amongst inanimate substances, a clod, a pebble, a liquid drop might be; but never was a watch, a telescope, an organized body of any kind, answering a valuable purpose by a complicated mechanism, the effect of chance. In no assignable instance hath such a thing existed without intention somewhere.

IV. There is another answer, which has the same effect as the resolving of things into chance; which answer would persuade us to believe, that the eye, the animal to which it belongs, every other animal, every plant, indeed every organized body which we see, are only so many out of the possible varieties and combinations of being, which the lapse of infinite ages has brought into existence; that the present world is the relic of that variety; millions of other bodily forms and other species having perished, being by the defect of their constitution incapable of preservation, or of continuance by generation. Now there is no foundation whatever for this conjecture in any thing which we observe in the works of nature; no such experiments are going on at present; no such energy operates, as that which is here supposed, and which should be constantly pushing into existence new varieties of beings. Nor are there any appearances to support an opinion, that every possible combination of vegetable or animal structure has formerly been tried. Multitudes of conformations, both of vegetables and animals, may be conceived capable of existence and succession, which yet do not exist. Perhaps almost as many forms of plants might have been found in the fields, as figures of plants can be delineated upon paper. A countless variety of animals might have existed, which do not exist. Upon the supposition here stated, we should see unicorns and mermaids, sylphs and centaurs, the fancies of painters, and the fables of poets, realized by examples. Or if it be alleged that these may transgress the limits of possible life and propagation, we might, at least, have nations of human beings without nails upon their fingers, with more or fewer fingers and toes than ten; some with one eye, others with one ear, with one nostril, or without the sense of smelling at all. All these, and a thousand other imaginable varieties, might live and propagate. We may modify any one species many different ways, all consistent with life, and with the actions necessary to preservation, although affording different degrees of conveniency and enjoyment to the animal. And if we carry these modifications through the different species which are known to subsist, their number would be incalculable. No reason can be given why, if these deperdits ever existed, they have now disappeared. Yet, if all possible existences have been tried, they must have formed part of the catalogue.

But moreover, the division of organized substances into animals and vegetables, and the distribution, and the sub-distribution of each into genera and species, which distribution is not an arbitrary act of the mind, but founded in the order which prevails in external nature, appear to me to contradict the supposition of the present world being the remains of an indefinite variety of existences; of a variety which rejects all plan. The hypothesis teaches, that every possible variety of being hath, at one time or other, found its way into existence, (by what cause or in what manner is not said,) and that those which were badly formed, perished; but how or why those which survived should be cast, as we see that plants and animals are cast, into regular classes, the hypothesis does not explain; or rather, the hypothesis is inconsistent with this phenomenon.

The hypothesis, indeed, is hardly deserving of the consideration which we have given to it. What should we think of a man who, because we had never ourselves seen watches, telescopes, stocking-mills, steam-engines, &c. made, knew not how they were made, or could prove by testimony when they were made, or by whom,—would have us believe that these machines, instead of deriving their curious structures from the thought and design of their inventors and contrivers, in truth derive them from no other origin than this, viz. that a mass of metals and other materials having run when melted into all possible figures, and combined themselves in all possible forms and shapes, and proportions, these things which we see, are what were left from the accident, as best worth preserving; and, as such, are become the remaining stock of a magazine, which, at one time or other, has, by this means, contained every mechanism, useful and useless, convenient and inconvenient, into which such like materials could be thrown? I cannot distinguish the hypothesis as applied to the works of nature, from this solution, which no one would accept, as applied to a collection of machines.

V. To the marks of contrivance discoverable in animal bodies, and to the argument deduced from them, in proof of design, and of a designing Creator, this turn is sometimes attempted to be given, namely, that the parts were not intended for the use, but that the use arose out of the parts. This distinction is intelligible. A cabinet-maker rubs his mahogany with fish-skin; yet it would be too much to assert that the skin of the dog-fish was made rough and granulated on purpose for the polishing of wood, and the use of cabinet-makers. Therefore the distinction is intelligible. But I think that there is very little place for it in the works of nature. When roundly and generally affirmed of them, as it hath sometimes been, it amounts to such another stretch of assertion, as it would be to say, that all the implements of the cabinet-maker's work-shop, as well as the fish-skin, were substances accidentally configurated, which he had picked up, and converted to his use; that his adzes, saws, planes, and gimlets, were not made, as we suppose, to hew, cut, smooth, shape out, or bore wood with; but that, these things being made, no matter with what design, or whether with any, the cabinet-maker perceived that they were applicable to his purpose, and turned them to account.

But, again. So far as this solution is attempted to be applied to those parts of animals, the action of which does not depend upon the will of the animal, it is fraught with still more evident absurdity. Is it possible to believe that the eye was formed without any regard to vision; that it was the animal itself which found out, that, though formed with no such intention, it would serve to see with; and that the use of the eye, as an organ of sight, resulted from this discovery, and the animal's application of it? The same question may be asked of the ear; the same of all the senses. None of the senses fundamentally depend upon the election of the animal; consequently, neither upon his sagacity, nor his experience. It is the impression which objects make upon them, that constitutes their use. Under that impression, he is passive. He may bring objects to the sense, or within its reach; he may select these objects: but over the impression itself he has no power, or very little; and that properly is the sense.

Secondly, there are many parts of animal bodies, which seem to depend upon the will of the animal in a greater degree than the senses do, and yet, with respect to which, this solution is equally unsatisfactory. If we apply the solution to the human body, for instance, it forms itself into questions, upon which no reasonable mind can doubt; such as, whether the teeth were made expressly for the mastication of food, the feet for walking, the hands for holding; or whether, these things being as they are, being in fact in the animal's possession, his own ingenuity taught him that they were convertible to these purposes, though no such purposes were contemplated in their formation?

All that there is of the appearance of reason in this way of considering the subject is, that in some cases the organization seems to determine the habits of the animal, and its choice, to a particular mode of life; which, in a certain sense, may be called "the use arising out of the part." Now to all the instances, in which there is any place for this suggestion, it may be replied, that the organization determines the animal to habits beneficial and salutary to itself; and that this effect would not be seen so regularly to follow, if the several organizations did not bear a concerted and contrived relation to the substance by which the animal was surrounded. They would, otherwise, be capacities without objects; powers without employment. The web-foot determines, you say, the duck to swim; but what would that avail, if there were no water to swim in? The strong hooked bill, and sharp talons, of one species of bird, determine it to prey upon animals; the soft straight bill, and weak claws, of another species, determine it to pick up seeds: but neither determination could take effect in providing for the sustenance of the birds, if animal bodies and vegetable seeds did not lie within their reach. The peculiar conformation of the bill, and tongue, and claws of the woodpecker,* determines that bird to search for his food amongst the insects lodged behind the bark, or in the wood, of decayed trees: but what would this profit him, if

* The bill of the woodpecker is thick, strong, and sharp: tongue long, its tip horny and barbed: tail composed of ten stiff feathers bending downwards, which in climbing assist in its support; the claws are strong and hooked, and, as in all climbing birds, have two placed forwards, and two backwards, by which they take a firm hold of the bark of trees. See TAB. XXVII. Fig. 1, 2, 3.

there were no trees, no decayed trees, no insects lodged under their bark, or in their trunk? The proboscis with which the bee is furnished, determines him to seek for honey: but what would that signify, if flowers supplied none? Faculties thrown down upon animals at random, and without reference to the objects amidst which they are placed, would not produce to them the services and benefits which we see; and if there be that reference, then there is intention.

Lastly, The solution fails entirely when applied to plants. The parts of plants answer their uses without any concurrence from the will or choice of the plant.

VI. Others have chosen to refer every thing to a *principle of order* in nature. A principle of order is the word: but what is meant by a principle of order, as different from an intelligent Creator, has not been explained either by definition or example; and, without such explanation, it should seem to be a mere substitution of words for reasons, names for causes. Order itself is only the adaptation of means to an end: a principle of order therefore can only signify the mind and intention which so adapts them. Or, were it capable of being explained in any other sense, is there any experience, any analogy to sustain it? Was a watch ever produced by a principle of order? and why might not a watch be so produced as well as an eye?

Furthermore, a principle of order, acting blindly and without choice, is negatived by the observation, that order is not universal; which it would be, if it issued from a constant and necessary principle: nor indiscriminate, which it would be, if it issued from an unintelligent principle. Where order is wanted, there we find it; where order is not wanted, *i. e.* where, if it prevailed, it would be useless, there we do not find it. In the structure of the eye, (for we adhere to our example,) in the figure and position of its several parts, the most exact order is maintained. In the forms of rocks and mountains, in the lines which bound the coasts of continents and islands, in the shape of bays and promontories, no order whatever is perceived, because it would have been superfluous. No useful purpose would have arisen from moulding rocks and mountains into regular solids, bounding the channel of the ocean by geometrical curves; or from the map of the world resembling a table of diagrams in Euclid's Elements, or Simpson's Conic Sections.

VII. Lastly, The confidence which we place in our observations upon the works of nature, in the marks which we discover of contrivance, choice, and design, and in our reasoning upon the proofs afforded us, ought not to be shaken, as it is sometimes attempted to be done, by bringing forward to our view our own ignorance, or rather the general imperfection of our knowledge of nature.

Nor, in many cases, ought this consideration to affect us, even when it respects some parts of the subject immediately under our notice. True fortitude of understanding consists in not suffering what we know to be disturbed by what we do not know. If we perceive a useful end, and means adapted to that end, we perceive enough for our conclusion. If these things be clear, no matter what is obscure. The argument is finished. For instance; if the utility of vision to the animal which enjoys it, and the adaptation of the *eye* to this office, be evident and certain, (and I can mention nothing which is more so,) ought it to prejudice the inference which we draw from these premises, that we cannot explain the use of the spleen? Nay, more; if there be parts of the eye, *viz.* the cornea, the crystalline, the retina, in their substance, figure, and position, manifestly suited to the formation of an image by the refraction of rays of light, at least, as manifestly as the glasses and tubes of a dioptric telescope are suited to that purpose; it concerns not the proof which these afford of design, and of a designer, that there may perhaps be other parts, certain muscles, for instance, or nerves in the same eye, of the agency or effect of which we can give no account; any more than we should be inclined to doubt, or ought to doubt, about the construction of a telescope, *viz.* for what purpose it was constructed, or whether it were constructed at all, because there belonged to it certain screws and pins, the use or action of which we did not comprehend. I take it to be a general way of infusing doubts and scruples into the mind, to recur to its own ignorance, its own imbecility: to tell us that upon these subjects we know little; that little imperfectly; or rather, that we know nothing properly about the matter. These suggestions so fall in with our consciousness, as sometimes to produce a general distrust of our faculties and our conclusions. But this is an unfounded jealousy. The uncertainty of one thing does not necessarily affect the certainty of another thing. Our ignorance of many points need not suspend our assurance of a few. Before we yield, in any particular instance, to the scepticism which this sort of insinuation would induce, we ought accurately to ascertain, whether our ignorance or doubt concern those precise points upon which our conclusion rests. Other points are nothing. Our ignorance of other points may be of no consequence to these, though they be points, in various respects, of great importance. A just reasoner removes from his consideration, not only what he knows, but what he does not know, touching matters not strictly connected with his argument, *i. e.* not forming the very steps of his deduction; beyond these, his knowledge and his ignorance are alike relative.

CHAPTER VI.

THE ARGUMENT CUMULATIVE.

WERE there no example in the world of contrivance, except that of the *eye*, it would be alone sufficient to support the conclusion which we draw from it, as to the necessity of an intelligent Creator. It could never be got rid of; because it could not be accounted for by any other supposition, which did not contradict all the principles we possess of knowledge: the principles, according to which things do, as often as they can be brought to the test of experience, turn out to be true or false. Its coats and humours, constructed as the lenses of a telescope are constructed, for the refraction of rays of light to a point, which forms the proper office of the organ: the provision in its muscles for turning its pupil to the object, similar to that which is given to the telescope by screws, and upon which power of direction in the eye, the exercise of its office as an optical instrument depends; the further provision for its defence, for its constant lubricity and moisture, which we see in its socket and its lids, in its gland for the secretion of the matter of tears, its outlet or communication with the nose for carrying off the liquid after the eye is washed with it; —these provisions compose altogether an apparatus, a system of parts, a preparation of means, so manifest in their design, so exquisite in their contrivance, so successful in their issue, so precious, and so infinitely beneficial in their use, as, in my opinion, to bear down all doubt that can be raised upon the subject. And what I wish, under the title of the present chapter, to observe is, that if other parts of nature were inaccessible to our inquiries, or even if other parts of nature presented nothing to our examination but disorder and confusion, the validity of this example would remain the same. If there were but one watch in the world, it would not be less certain that it had a maker. If we had never in our lives seen any but one single kind of hydraulic machine, yet, if of that one kind we understood the mechanism and use, we should be as perfectly assured that it proceeded from the hand, and thought, and skill, of a workman, as if we visited a museum of the arts, and saw collected there twenty different kinds of machines for drawing water, or a thousand different kinds for other purposes. Of this point, each machine is a proof, independently of all the rest. So it is with the evidences of a Divine agency. The proof is not a conclusion which lies at the end of a chain of reasoning, of which chain each instance of contrivance is only a link, and of which, if one link fail, the whole falls; but it is an argument separately supplied by every separate example. An error in stating an example affects only that example. The argument is cumulative, in the fullest sense of that term. The eye proves it without the ear; the ear without the eye. The proof in each example is complete; for when the design of the part, and the conduciveness of its structure to that design is shewn, the mind may set itself at rest; no future consideration can detract any thing from the force of the example.

CHAPTER VII.

OF THE MECHANICAL AND IMMECHANICAL PARTS AND FUNCTIONS OF ANIMALS AND VEGETABLES.

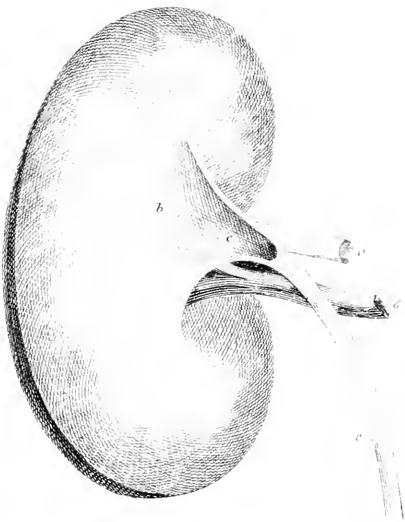
It is not that *every* part of an animal or vegetable has not proceeded from a contriving mind; or that every part is not constructed with a view to its proper end and purpose, according to the laws belonging to, and governing the substance or the action made use of in that part; or that each part is not so constructed as to effectuate its purpose whilst it operates according to these laws; but it is because these laws themselves are not in all cases equally understood; or, what amounts to nearly the same thing, are not equally exemplified in more simple processes, and more simple machines; that we lay down the distinction, here proposed, between the mechanical parts and other parts of animals and vegetables.

For instance; the principle of muscular motion, viz. upon what cause the swelling of the belly of the muscle, and consequent contraction of its tendons, either by an act of the will, or by involuntary irritation, depends, is wholly unknown to us. The substance employed, whether it be fluid, gaseous, elastic, electrical, or none of these, or nothing resembling these, is also unknown to us: of course, the laws belonging to that substance, and which regulate its action, are unknown to us. We see nothing similar to this contraction in any machine which we can make, or any process which we can execute. So far (it is confessed) we are in ignorance, but no farther. This power and principle, from whatever cause it proceeds, assumed, being the collocation of the fibres to receive the principle, the disposition of the muscles for the use and application of the power, is mechanical; and is as intelligible as the adjustment of the wires and strings by which a puppet is moved. We see, therefore, as far as respects the subject before us, what is not mechanical in the animal frame, and what is. The nervous influence (for we are often obliged to give names to things which we know little about)—I say the nervous influence, by which the belly, or middle of the muscle is swelled, is not mechanical. The utility of the effect we perceive; the means, or the preparation of means, by which it is produced, we do not. But obscurity as to the origin of muscular motion brings no doubtfulness into our observations upon the sequel of the process: which observations relate, 1*st*, To the constitution of the muscle; in consequence of which constitution, the swelling of the belly or middle part is necessarily and mechanically followed by a retraction of the tendons: 2*dly*, To the number and variety of the muscles, and the corresponding number and variety of useful powers which they supply to the animal; which is astonishingly great: 3*dly*, To the judicious, (if we may be permitted to use that term, in speaking of the Author, or of the works of nature,) to the wise and well-contrived disposition of each muscle for its specific purpose; for moving the joint this way, and that way, and the other way; for pulling and drawing the part to which it is attached, in a determinate and particular direction; which is a mechanical operation, exemplified in a multitude of instances. To mention only one: the tendon of the trochlear muscle of the eye,* to the end that it may draw in the line re-

* TAB. VI. Fig. 1. The *trochlear, or superior oblique* muscle, arises with the straight muscles from the bottom of the orbit. Its muscular portion, *a*, is extended over the upper part of the eye-ball, and gradually assumes the form of a smooth round tendon, *b*. which passes through the pulley, *c*, which is fixed to

TAB. VI.

1



2

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quired, is passed through a cartilaginous ring, at which it is reverted, exactly in the same manner as a rope in a ship is carried over a block or round a stay, in order to make it pull in the direction which is wanted. All this, as we have said, is mechanical; and is accessible to inspection, as capable of being ascertained, as the mechanism of the automaton in the Strand. Suppose the automaton to be put in motion by a magnet, (which is probable,) it will supply us with a comparison very apt for our present purpose. Of the magnetic effluvium, we know perhaps as little as we do of the nervous fluid. But, magnetic attraction being assumed, (it signifies nothing from what cause it proceeds,) we can trace, or there can be pointed out to us, with perfect clearness and certainty, the mechanism, viz. the steel bars, the wheels, the joints, the wires, by which the motion so much admired is communicated to the fingers of the image: and to make any obscurity, or difficulty, or controversy in the doctrine of magnetism, an objection to our knowledge or our certainty concerning the contrivance, or the marks of contrivance displayed in the automaton, would be exactly the same thing, as it is to make our ignorance (which we acknowledge) of the cause of nervous agency, or even of the substance and

the inner edge of the orbit, *d*, then returning backwards and downwards, *e*, is inserted into the sclerotic membrane, *f*. The use of this muscle is to bring the eye forwards, and to turn the pupil downwards and outwards.

structure of the nerves themselves, a ground of question or suspicion as to the reasoning which we institute concerning the mechanical part of our frame. That an animal is a machine, is a proposition neither correctly true nor wholly false. The distinction which we have been discussing, will serve to show how far the comparison, which this expression implies, holds; and wherein it fails. And whether the distinction be thought of importance or not, it is certainly of importance to remember, that there is neither truth nor justice in endeavouring to bring a cloud over our understandings, or a distrust into our reasonings upon this subject, by suggesting that we know nothing of voluntary motion, of irritability, of the principle of life, of sensation, of animal heat, upon all which the animal functions depend; for, our ignorance of these parts of the animal frame concerns not at all our knowledge of the mechanical parts of the same frame. I contend, therefore, that there is mechanism in animals; that this mechanism is as properly such, as it is in machines made by art; that this mechanism is intelligible and certain; that it is not the less so, because it often begins or terminates with something which is not mechanical; that whenever it is intelligible and certain, it demonstrates intention and contrivance, as well in the works of nature as in those of art; and that it is the best demonstration which either can afford.

But whilst I contend for these propositions, I do not exclude myself from asserting, that there may be, and that there are, other cases, in which, although we cannot exhibit mechanism, or prove indeed that mechanism is employed, we want not sufficient evidence to conduct us to the same conclusion.

There is what may be called the *chemical* part of our frame; of which, by reason of the imperfection of our chemistry, we can attain to no distinct knowledge; I mean, not to a knowledge, either in degree or kind, similar to that which we possess of the mechanical part of our frame. It does not, therefore, afford the same species of argument as that which mechanism affords; and yet it may afford an argument in a high degree satisfactory. The *gastric juice*,* or the liquor which digests the food in the stomachs of animals, is of this class. Of all menstrua, it is the most active, the most universal. In the human stomach, for instance, consider what a variety of strange substances, and how widely different from one another, it, in a few hours, reduces to an uniform pulp, milk, or mucilage. It seizes upon every thing, it dissolves the texture of almost every thing that comes in its way. The flesh of perhaps all animals; the seeds and fruits of the greatest number of plants; the roots, and stalks, and leaves of many, hard and

* The *gastric juice* is a fluid produced by the minute glands in the stomach called follicles.

tough as they are, yield to its powerful pervasion. The change wrought by it is different from any chemical solution which we can produce, or with which we are acquainted, in this respect, as well as many others, that, in our chemistry, particular menstrua act only upon particular substances. Consider, moreover, that this fluid, stronger in its operation than a caustic alkali or mineral acid, than red precipitate, or aqua-fortis itself, is nevertheless as mild, and bland, and inoffensive to the touch or taste, as saliva or gum-water, which it much resembles. Consider, I say, these several properties of the digestive organ, and of the juice with which it is supplied, or rather with which it is made to supply itself, and you will confess it to be entitled to a name, which it has sometimes received, that of "the chemical wonder of animal nature."*

Still we are ignorant of the composition of this fluid, and of the mode of its action; by which is meant, that we are not capable, as we are in the mechanical part of our frame, of collating it with the operations of art. And this I call the imperfection of our chemistry; for should the time ever arrive, which is not perhaps to be despaired of,

* This description of the gastric juice is perfectly correct; the object of digestion is the formation of *chyle*, a matter destined for repairing the continual waste of the animal machine. Independent of this general object, this function likewise contributes to nutrition, and even to life in general in various ways. See notes on the functions of the stomach, Chap. x.

when we can compound ingredients, so as to form a solvent which will act in the manner in which the gastric juice acts, we may be able to ascertain the chemical principles upon which its efficacy depends, as well as from what part, and by what concoction, in the human body, these principles are generated and derived.

In the mean time, ought that, which is in truth the defect of our chemistry, to hinder us from acquiescing in the inference, which a production of nature, by its place, its properties, its action, its surprising efficacy, its invaluable use, authorizes us to draw in respect of a creative design?

Another most subtile and curious function of animal bodies is *secretion*.* This function is semi-chemical and semi-mechanical; exceedingly important and diversified in its effects, but obscure in its process and in its apparatus. The importance of the secretory organs is but too well attested by the diseases, which an excessive, a deficient, or a vitiated secretion is almost sure of producing. A single secretion being wrong, is enough to make life miserable, or sometimes to destroy it. Nor is the variety less than the importance. From one and the same blood (I speak of the human body)

* The term *secretion* expresses that function by which a gland, or other organ, separates from the blood a fluid hurtful or useless to it, or destined for some further purpose in the varied functions of the animal economy. The *urine*, *bile*, *saliva*, and the *milk* of animals in general, and the *venom* of poisonous serpents in particular, are instances of different *secretions*.

about twenty different fluids are separated; in their sensible properties, in taste, smell, colour, and consistency, the most unlike one another that is possible; thick, thin, salt, bitter, sweet: and, if from our own we pass to other species of animals, we find amongst their secretions, not only the most various, but the most opposite properties; the most nutricious aliment, the deadliest poison; the sweetest perfumes,* the most fœtid odours.† Of these the greater part, as the gastric juice, the saliva, the bile, the slippery mucilage which lubricates the joints, the tears which moisten the eye, the wax which defends the ear, are, after they are secreted made use of in the animal economy; are evidently subservient, and are actually contributing to the utilities of the animal itself. Other fluids seem to be separated only to be rejected. That this also is necessary (though why it was originally necessary, we cannot tell) is shown by the consequence of the separation being long suspended; which consequence is disease and death. Akin to secretion, if not the same thing, is assimilation, by

* The costly and powerful perfume *musk*, is obtained from an animal inhabiting the most elevated regions of Asia, particularly of the Atlayan Alps, and the mountains which divide Thibet from China. It is a gentle and timid animal of the deer tribe; on the abdomen of the male there is an oval bag, about three inches long and two broad, and having a small orifice, beset with short hair, which is empty in the young animal, but in the adult is filled with a *secreted matter* known by the name of musk.

† Fœtid odours, from animal bodies, are exhalations rather than secretions; there is certainly an analogy, but there are distinctions which are noticed in a subsequent note.

which one and the same blood is converted into bone, muscular flesh, nerves, membranes, tendons; things as different as the wood and iron, canvass and cordage, of which a ship with its furniture is composed. We have no operation of art wherewith exactly to compare all this, for no other reason perhaps than that all operations of art are exceeded by it. No chemical election, no chemical analysis or resolution of a substance into its constituent parts, no mechanical sifting or division, that we are acquainted with, in perfection or variety come up to animal secretion. Nevertheless, the apparatus and process are obscure; not to say absolutely concealed from our inquiries. In a few, and only a few instances, we can discern a little of the constitution of a gland. In the kidneys of large animals, we can trace the emulgent artery dividing itself into an infinite number of branches; their extremities everywhere communicating with little round bodies, in the substance of which bodies the secret of the machinery seems to reside, for there the change is made. We can discern pipes laid from these round bodies towards the pelvis, which is a basin within the solid of the kidney. We can discern these pipes joining and collecting together into larger pipes; and, when so collected, ending in innumerable papillæ, through which the secreted fluid is continually oozing into its receptacal.* This is all we know

* The kidneys lie in the abdomen, on each side of the vertebræ

of the mechanism of a gland, even in the case in which it seems most capable of being investigated. Yet to pronounce that we know nothing of animal secretion, or nothing satisfactorily, and with that concise remark to dismiss the article from our argument, would be to dispose of the subject very hastily and very irrationally. For the purpose which we want, that of evincing intention, we know a great deal. And what we know is this. We see the blood carried by a pipe, conduit, or duct, *to* the gland. We see an organized apparatus, be its construction or action what it will, which we call that gland. We see the blood, or part of the blood, after it has passed through and undergone the action of the gland, coming *from* it by an emulgent vein, *i. e.* by another pipe or conduit. And we see also at the same time a new and specific fluid issuing from the same gland by its excretory duct, *i. e.* by a third pipe or conduit; which new fluid is in some cases discharged out of the body, in more cases

of the loins. Like other glands they are lobulated, but in the kidney each lobe is composed of converging transparent tubes, terminating in larger ducts at the points of the papillæ or "little round bodies" here mentioned. The natural office of the kidneys is to draw off fluids having saline, and other substances in solution, the retention of which would be injurious to the animal system. Fig. 2. A section of the human kidney; *a*, the *emulgent artery* which conveys the blood to *b*, the *papillæ*, where the peculiar fluid is secreted; from whence it passes by tubes into *c*, the *pelvis; e*, the *ureter*, or tube, which conducts the secretion to its receptacle; *d*, the *emulgent vein* for returning the blood after it has been submitted to the action of the gland.

retained within it, and there executing some important and intelligent office.* Now supposing, or admitting, that we know nothing of the proper internal constitution of a gland, or of the mode of its acting upon the blood; then our situation is precisely like that of an unmechanical looker-on, who stands by a stocking-loom, a corn-mill, a carding-machine, or a threshing-machine, at work, the fabric and mechanism of which, as well as all that passes within, is hidden from his sight by the outside case; or, if seen, would be too complicated for his uninformed, uninstructed understanding to comprehend. And what is that situation? This spectator, ignorant as he is, sees at one end a material enter the machine, as unground grain the mill, raw cotton the carding-machine, sheaves of unthreshed corn the threshing-machine; and, when he casts his eye to the other end of the apparatus, he sees the material issuing from it in a new state; and, what is more, in a state manifestly adapted to future uses; the grain is meal fit for the making of bread, the wool in rovings ready for spinning into threads, the sheaf in corn dressed for the mill. Is it necessary that this man, in order to be convinced that design, that intention, that contrivance has been employed about

* Secreted fluids are always destined to be expelled from the body; those matters derived from the blood, to be employed in the animal functions as e. g. the synovial fluid, and mucous, are not termed secretions but exhalations.

the machine, should be allowed to pull it to pieces; should be enabled to examine the parts separately; explore their action upon one another, or their operation, whether simultaneous or successive, upon the material which is presented to them? He may long to do this to gratify his curiosity; he may desire to do it to improve his theoretic knowledge; or he may have a more substantial reason for requesting it, if he happen, instead of a common visitor, to be a millwright by profession, or a person sometimes called in to repair such-like machines when out of order; but for the purpose of ascertaining the existence of counsel and design in the formation of the machine, he wants no such intromission or privity. What he sees is sufficient. The effect upon the material, the change produced in it, the utility of that change for future applications, abundantly testify, be the concealed part of the machine or of its construction what it will, the hand and agency of a contriver.

If any confirmation were wanting to the evidence which the animal secretions afford of design, it may be derived, as has been already hinted, from their variety, and from their appropriation to their place and use. They all come from the same blood: they are all drawn off by glands: yet the produce is very different, and the difference exactly adapted to the work which is to be done, or the end to be answered. No account can be given of this, without resorting to appointment. Why, for instance, is the saliva, which is diffused over the seat of taste, insipid, whilst so many others of the secretions, the urine, the tears, and the sweat, are salt? Why does the gland within the ear separate a viscid substance, which defends that passage;* the gland in the outer angle of the eye, a thin brine, which washes the ball? Why is the synovia of the joints mucilaginous; the bile bitter, stimulating, and soapy? Why does the juice which flows into the stomach, contain powers, which make that organ the great laboratory, as it is by its situation the recipient, of the materials of future nutrition? These are all fair questions; and no answer can be given to them, but what calls in intelligence and intention.†

My object in the present chapter has been to teach three things: first, that it is a mistake to suppose that, in reasoning from the appearances of

* Within the tube of the ear there are a set of small glands called the *glandulæ cerumenosæ*. These glands secrete the wax of the ear, and this secretion, with the hairs which stand across the passage, guards the internal parts of the ear from insects.

† *Exhalation* is another function continually going on in the animal system similar to *secretion*, both separate fluids from the blood. Their distinctions are as follow:—Exhalation takes place on the surface of the body as in perspiration, or from membranous or cellular tissues, as the vapour from the lungs, the separation of fat, &c. In secretion there is an intermediate organ to separate the fluid, as the liver for secreting the bile, the salivary glands the saliva, &c. From accurate experiments instituted by Lavoisier and Seguin it has been ascertained, that the mean quantity of exhalation from the surface of the human body and from the lungs in twenty-four hours amounts to somewhat more than four pounds.

Annales de Chèmie, tom. xc. p. 14.

nature, the imperfection of our knowledge proportionably affects the certainty of our conclusion; for in many cases it does not affect it at all: secondly, that the different parts of the animal frame may be classed and distributed, according to the degree of exactness with which we can compare them with works of art: thirdly, that the *mechanical* parts of our frame, or those in which this comparison is most complete, although constituting, probably, the coarsest portions of nature's workmanship, are the most proper to be alleged as proofs and specimens of design.

CHAPTER VIII.

OF MECHANICAL ARRANGEMENT IN THE HUMAN FRAME.

We proceed, therefore, to propose certain examples taken out of this class: making choice of such as, amongst those which have come to our knowledge, appear to be the most striking, and the best understood; but obliged, perhaps, to postpone both these recommendations to a third; that of the example being capable of explanation without plates, or figures, or technical language.

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OF THE BONES.

I. I challenge any man to produce, in the joints and pivots of the most complicated or the most flexible machine that was ever contrived, a construction more artificial, or more evidently artificial, than that which is seen in the vertebræ of the *human neck*.*—Two things were to be done. The head was to have the power of bending forward and backward, as in the act of nodding, stooping, looking upward or downward; and, at the same time, of turning itself round upon the body to a certain extent, the quadrant we will say, or rather, perhaps, a hundred and twenty degrees of a circle. For these two purposes, two distinct contrivances are employed: first, the head rests immediately upon the uppermost of the vertebræ and is united to it by a *hinge*-joint; upon which joint the head plays freely forward and backward, as far either way as is necessary, or as the ligaments allow; which was the first thing required.—But then the rotatory motion is unprovided for. Therefore, secondly, to make the head capable of this, a farther mechanism is introduced; not between the head and the uppermost bone of the neck, where the hinge is, but between that

* TAB. VII. Fig. 1. A representation of the head and the neck; the latter is composed of seven bones called *vertebræ*.

bone, and the bone next underneath it.* It is a mechanism resembling a *tenon and mortice*. This second, or uppermost bone but one, has what anatomists call a process, viz. a projection, somewhat similar, in size and shape, to a tooth ; which tooth entering a corresponding hole or socket in the bone above it, forms a pivot or axle, upon which that upper bone, together with the head which it supports, turns freely in a circle ; and as far in the circle as the attached muscles permit the head to turn. Thus are both motions perfect, without interfering with each other. When we nod the head, we use the hinge-joint, which lies between the head and the first bone of the neck. When we turn the head round, we use the tenon and mortice, which runs between the first bone of the neck and the second. We see the same contrivance, and the same principle, employed in the frame or mounting of a telescope. It is occasionally requisite, that the object-end of the instrument be moved up and down, as well as horizontally, or equatorially. For the vertical motion, there is a hinge, upon which the telescope plays ; for the horizontal or equatorial motion, an axis upon which the telescope and the hinge turn

* Fig. 2. Exhibits the first and second vertebræ, with their mode of connexion. The uppermost vertebra, termed the *atlas*, from its supporting the globe of the head, has an oval *concave* surface on either side, *a*, *a*, for the reception of two corresponding *convex* surfaces placed on the lower part of the head, in such a manner as only to admit of the action of bending and raising the head.

round together. And this is exactly the mechanism which is applied to the motion of the head: nor will any one here doubt of the existence of counsel and design, except it be by that debility of mind, which can trust to its own reasonings in nothing.

We may add, that it was, on another account also, expedient, that the motion of the head backward and forward should be performed upon the upper surface of the first vertebra: for, if the first vertebra itself had bent forward, it would have brought the spinal marrow, at the very beginning of its course, upon the point of the tooth.*

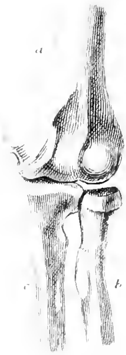
II. Another mechanical contrivance, not unlike the last in its object, but different and original in its means, is seen in what anatomists call the *fore-arm*; that is, in the arm from the elbow to the wrist. Here, for the perfect use of the limb, two motions are wanted; a motion of the elbow

* Fig. 4. The second vertebra, called *dentata*, has two plane surfaces, *a*, *a*, adapted to the planes, *a*, *a*, Fig. 3. of the atlas: and this manner of articulation provides for the turning of the head laterally in almost every direction. Fig. 2. and 4. *b*, *b*, shews the *tooth-like process* which affords a firm pivot for the production of the lateral motion thus described. This process is received into a corresponding *indentation* of the atlas, Fig. 3. *b*, and a strong ligament passes behind it, serving as an effectual security against dislocation, and consequent compression of the spinal marrow. Fig. 4. *d*, marks the situation of the spinal marrow, which passes through the ring of each vertebra. The letter *c* indicates a perforation in the lateral process; and, as there is a corresponding perforation in each lateral, or as it is termed *transverse* process of the seven *cervical* vertebræ, a continuous passage is thus formed for the protection of two important blood-vessels destined to supply the brain.

backward and forward, which is called a reciprocal motion; and a rotatory motion, by which the palm of the hand, as occasion requires, may be turned upward. How is this managed? The fore-arm, it is well known, consists of two bones lying alongside each other, but touching only towards the ends. One, and only one of these bones, is joined to the humerus, or upper part of the arm, at the elbow; the other alone, to the hand at the wrist. The first by means, at the elbow, of a hinge-joint, (which allows only of motion in the same plane,) swings backward and forward, carrying along with it the other bone, and the whole fore-arm. In the mean time, as often as there is occasion to turn the palm upward, that other bone, to which the hand is attached, rolls upon the first, by the help of a groove or hollow near each end of one bone, to which is fitted a corresponding prominence in the other. If both bones had been joined to the cubit, or upper arm, at the elbow, or both to the hand at the wrist, the thing could not have been done. The first was to be at liberty at one end, and the second at the other; by which means the two actions may be performed together. The great bone, which carries the fore-arm, may be swinging upon its hinge at the elbow, at the very time that the lesser bone, which carries the hand, may be turning round it in the grooves.* The

* TAB. VIII. Fig. 1. *a*, the *humerus*; the head, *b*, is a portion

TAB. VIII.



management also of these grooves, or rather of the tubercles and grooves, is very observable. The two bones are called the *radius* and the *ulna*. Above, *i. e.* towards the elbow, a tubercle of the radius plays into a socket of the ulna: whilst below, *i. e.* towards the wrist, the radius finds the socket, and the ulna the tubercle.* A single bone in the fore-arm, with a ball and socket joint at the elbow, which admits of motion in all directions, might, in some degree, have answered the purpose of both moving the arm and turning the hand. But how much better it is accomplished by the present mechanism, any person may convince himself, who puts the ease and quickness, with which he can shake his hand at the wrist circularly, (moving likewise, if he pleases, his arm at the elbow at the same time,) in competition with the comparatively slow and laborious motion with which his arm can be made to turn round at the shoulder, by the aid of a ball and socket joint.

III. The *spine*, or back-bone, is a chain of

of a sphere, and exhibits an example of the *ball and socket*, or universal joint; *c*, the *hinge joint*, instanced in the elbow; *d*, the *radius*; *e*, the *ulna* The radius belongs more peculiarly to the wrist, being the bone which supports the hand, and which turns with it in all its revolving motions. The ulna principally belongs to the elbow joint, for by it we perform all the actions of bending or extending the arm.

* Fig. 2. shews the connexion of the radius, *b*, with the ulna, *c*, at the elbow: *a*, the humerus. The mode of articulation at the wrist is seen, Fig. 1.

joints of very wonderful construction.* Various, difficult, and almost inconsistent offices were to be executed by the same instrument. It was to be firm, yet flexible, (now I know no chain made by art, which is both these; for by firmness I mean, not only strength, but stability:) *firm*, to support the erect position of the body; *flexible*, to allow of the bending of the trunk in all degrees of curvature. It was farther also (which is another, and quite a distinct purpose from the rest) to become a pipe or conduit for the safe conveyance from the brain, of the most important fluid of the animal frame, that, namely, upon which all voluntary motion depends, the spinal marrow; a substance not only of the first necessity to action, if not to life, but of a nature so delicate and tender, so susceptible, and so impatient of injury, as that any unusual pressure upon it, or any considerable obstruction of its course, is followed by paralysis or death. Now the spine was not only to furnish the main trunk for the passage of the medullary substance from the brain, but to give out, in the course of its progress, small pipes therefrom, which being afterwards

* Tab. IX. Fig. 1. The *human spine*, so named from the series of sharp processes projecting from the posterior part of the vertebræ. The spine consists of *seven* vertebræ of the neck, distinguished by the perforations in their transverse processes; of *twelve* belonging to the back, and marked by depressions for the heads of the ribs; and, lastly, of *five* belonging to the loins, which are larger than the other vertebræ.

TAB. IX

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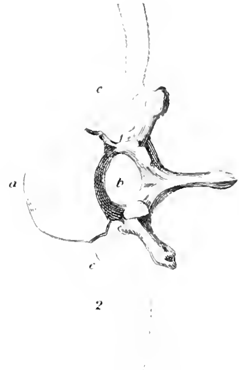

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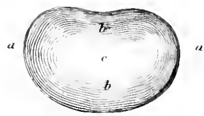

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5. p. 103

indefinitely subdivided, might, under the name of nerves, distribute this exquisite supply to every part of the body. The same spine was also to serve another use not less wanted than the preceding, viz. to afford a fulcrum, stay, or basis, (or, more properly speaking, a series of these,) for the insertion of the muscles which are spread over the trunk of the body; in which trunk there are not, as in the limbs, cylindrical bones, to which they can be fastened: and, likewise, which is a similar use, to furnish a support for the ends of the ribs to rest upon.

Bespeak of a workman a piece of mechanism, which shall comprise all these purposes, and let him set about to contrive it; let him try his skill upon it; let him feel the difficulty of accomplishing the task, before he be told how the same thing is effected in the animal frame. Nothing will enable him to judge so well of the wisdom which has been employed; nothing will dispose him to think of it so truly.

First, for the firmness, yet flexibility, of the spine; it is composed of a great number of bones (in the human subject, of twenty-four) joined to one another, and compacted by broad bases. The breadth of the bases upon which the parts severally rest, and the closeness of the junction, give to the chain its firmness and stability; the number of parts, and consequent frequency of joints, its flexibility. Which flexibility, we may also observe, varies in different parts of the chain; is least in the back, where strength, more than flexure, is wanted; greater in the loins, which it was necessary should be more supple than the back; and greatest of all in the neck, for the free motion of the head. Then, secondly, in order to afford a passage for the descent of the medullary substance, each of these bones is bored through the middle in such a manner, as that, when put together, the hole in one bone falls into a line, and corresponds with the holes in the two bones contiguous to it. By which means the perforated pieces, when joined, form an entire, close, uninterrupted channel; at least, whilst the spine is upright, and at rest. But, as a settled posture is inconsistent with its use, a great difficulty still remained, which was to prevent the vertebræ shifting upon one another, so as to break the line of the canal as often as the body moves or twists; or the joints gaping externally, whenever the body is bent forward, and the spine thereupon made to take the form of a bow. These dangers, which are mechanical, are mechanically provided against. The vertebræ, by means of their processes and projections, and of the articulations which some of these form with one another at their extremities, are so locked in and confined, as to maintain, in what are called the bodies, or broad surfaces of the bones, the relative position nearly unaltered; and to throw the change and the pressure, produced by flexion, almost entirely upon the intervening cartilages,* the springiness and yielding nature of whose substance admits of all the motion which is necessary to be performed upon them, without any chasm being produced by a separation of the parts. I say, of all the motion which is necessary; for although we bend our backs to every degree almost of inclination, the motion of each vertebra is very small: such is the advantage we receive from the chain being composed of so many links, the spine of so many bones. Had it consisted of three or four bones only, in bending the body, the spinal marrow must have been bruised at every angle. The reader need not be

* These intervening cartilages, more properly called *intervertebral fibro-cartilages*, are intimately adherent, by their superior and inferior surfaces, to the corresponding surfaces of the vertebræ.

Dr. Monro, senior, discovered their mechanism, and it is well deserving our notice. The hinge, and the ball and socket joint, are familiar to the mechanic; but the singular contrivance here mentioned by Paley, is a species of universal joint less understood, and which art never imitated. This moveable union is a mixture of cartilage and ligament, partaking of the property of both. On the outside (Fig. 5. *a*, *a*,) is a firm elastic rim of concentric fibres, within these, *b*, *b*, are smaller circles, gradually softer in their texture as they approach *c*, the centre, where it is altogether of a semi-liquid or mucous form. Thus each vertebra resting on a fluid fulcrum, or pivot, the motion to any side is easy, and quickly performed, the compressibility of this substance gradually increasing from the liquid centre to the fibro-cartilaginous circumference. Hence all the motions of the back bone, or bones, are performed on a fluid centre, surrounded by a perfectly elastic medium, which remarkable union of flat surfaces admits the requisite motion, and prevents the delicate texture of the spinal marrow, and brain, from sustaining injury by shocks in violent exercise.

told, that these intervening cartilages are gristles; and he may see them in perfection in a loin of veal. Their form also favours the same intention. They are thicker before than behind; so that, when we stoop forward, the compressible substance of the cartilage, yielding in its thicker and anterior part to the force which squeezes it, brings the surfaces of the adjoining vertebræ nearer to the being parallel with one another than they were before, instead of increasing the inclination of their planes, which must have occasioned a fissure or opening between them. Thirdly, for the medullary canal giving out in its course, and in a convenient order, a supply of nerves to different parts of the body, notches are made in the upper and lower edge of every vertebra, two on each edge, equi-distant on each side from the middle line of the back. When the vertebræ are put together, these notches, exactly fitting, form small holes, through which the nerves, at each articulation, issue out in pairs, in order to send their branches to every part of the body, and with an equal bounty to both sides of the body. The fourth purpose assigned to the same instrument is the insertion of the bases of the muscles, and the support of the ends of the ribs; and for this fourth purpose, especially the former part of it, a figure, specifically suited to the design, and unnecessary for the other purposes, is given to the constituent bones. Whilst they are plain, and round, and smooth, towards the front, where any roughness or projection might have wounded the adjacent viscera, they run out behind, and on each side, into long processes, to which processes the muscles necessary to the motions of the trunk are fixed; and fixed with such art, that, whilst the vertebræ supply a basis for the muscles, the muscles help to keep these bones in their position, or by their tendons to tie them together.*

That most important, however, and general property, viz. the strength of the compages, and the security against luxation, was to be still more specially consulted: for where so many joints were concerned, and where, in every one, derangement would have been fatal, it became a subject of studious precaution. For this purpose, the vertebræ are articulated, that is, the moveable joints between them are formed by means of those projections of their substance, which we have mentioned under the name of processes; and these so lock in with, and overwrap one another, as to secure the body of the vertebræ, not only from accidentally slipping, but even from being pushed out of its place by any violence short of that which would break the bone. I have often remarked and admired this structure in the chine of a hare. In this, as in many instances, a plain observer of

* Fig. 2. A separated *dorsal vertebra*; *a*, the body of the vertebra; *b*, the ring through which the spinal marrow passes; *c*, *c*, the articulating surfaces to which the ribs are united.

the animal economy may spare himself the disgust of being present at human dissections, and yet learn enough for his information and satisfaction, by even examining the bones of the animals which come upon his table. Let him take, for example, into his hands, a piece of the clean-picked bone of a hare's back; consisting, we will suppose, of three vertebræ. He will find the middle bone of the three so implicated by means of its projections or processes, with the bone on each side of it, that no pressure which he can use, will force it out of its place between them. It will give way neither forward, nor backward, nor on either side. In whichever direction he pushes, he perceives, in the form, or junction, or overlapping of the bones, an impediment opposed to his attempt; a check and guard against dislocation. In one part of the spine, he will find a still farther fortifying expedient, in the mode according to which the ribs are annexed to the spine. Each rib rests upon two vertebræ.* That is the thing to be remarked, and any one may remark it in carving a neck of mutton. The manner of it is this: the end of the rib is divided by a middle ridge into two surfaces; which surfaces are joined to the bodies of two contiguous vertebræ, the ridge applying itself to the intervening cartilage. Now

* There is an exception to this arrangement in the first, tenth, eleventh, and twelfth ribs, which have a single articular surface to a single vertebra

this is the very contrivance which is employed in the famous iron bridge at my door at Bishop-Wearmouth; and for the same purpose of stability; viz. the cheeks of the bars, which pass between the arches, ride across the joints, by which the pieces composing each arch are united. Each cross-bar rests upon two of these pieces at their place of junction; and by that position resists, at least in one direction, any tendency in either piece to slip out of its place. Thus perfectly, by one means or the other, is the danger of slipping laterally, or of being drawn aside out of the *line* of the back, provided against; and to withstand the bones being pulled asunder longitudinally, or in the direction of that line, a strong membrane runs from one end of the chain to the other, sufficient to resist any force which is ever likely to act in the direction of the back, or parallel to it, and consequently to secure the whole combination in their places. The general result is, that not only the motions of the human body necessary for the ordinary offices of life are performed with safety, but that it is an accident hardly ever heard of that even the gesticulations of a harlequin distort his spine.*

* The human spine possesses great strength combined with great flexibility. Its pyramidal form obviously contributes to the former. "The arrangement of the solid matter of which it is composed, is such as to contribute to the same effect: for that solid matter, instead of being collected into one solid mass, is diffused in such a manner as to resemble the structure of a sponge; and it is well

Upon the whole, and as a guide to those who may be inclined to carry the consideration of this subject farther, there are three views under which the spine ought to be regarded, and in all which it cannot fail to excite our admiration. These views relate to its articulations, its ligaments, and its perforation; and for that which is essential to every part, a secure communication with the brain.

The structure of the spine is not in general different in different animals. In the serpent tribe, however, it is considerably varied; but with a strict reference to the conveniency of the animal. For, whereas in quadrupeds the number of vertebræ is from thirty to forty in the serpent, it is nearly one hundred and fifty: whereas in

known, with reference to the strength of artificial columns, that the same quantity of matter being given for each, those columns which are hollow are stronger than those which are solid.

"The flexibility of the spine is secured to the utmost requisite extent by the number of articulations or joints which it possesses, as well as by the elasticity of the substance constituting those joints: and the projecting parts or processes of the several vertebræ, which serve for the insertion of the muscles and tendons which are to move the whole, are differently disposed in the neck, the back, and the loins, so as to be accommodated to the degree and kind of motion in each; thus the vertebræ of the neck admit of a lateral motion to a greater extent than those of the back, and the vertebræ of the back admit of flexion and extension to a greater degree than those of the neck; while the vertebræ of the loins, being intended for support rather than flexibility, have their processes so distributed, as to contribute principally to the former of those effects."

See Dr. Kidd's Introductory Lecture to a Course of Comparative Anatomy illustrative of Paley's Natural Theology, page 7, &c.

men and quadrupeds the surfaces of the bones are flat, and these flat surfaces laid one against the other, and bound tight by sinews; in the serpent the bones play one within another like a ball and socket,* so that they have a free motion upon one another in every direction: that is to say, in men and quadrupeds, firmness is more consulted; in serpents, pliancy.† Yet even pliancy is not obtained at the expense of safety. The back bone of a serpent, for coherence and flexibility, is one of the most curious pieces of animal mechanism with which we are acquainted.‡ The chain of a watch, (I mean the chain which passes between the spring-barrel and the fusee,) which aims at the same properties, is but a bungling piece of

* Derham's Physical Theology, p. 396.

† Fig. 5. A part of the spine of a very large serpent, drawn from a specimen belonging to the Anatomy school of Christ Church, Oxford. Fig. 3. shews the socket joint. Fig. 4, the rounded head, which is placed at the posterior extremity of the body of the vertebra, and at the anterior the deep depression (Fig. 3.) corresponds to it. The shape of the processes, which constitute the arches of the bodies of the vertebræ, is such as to permit free lateral motion.

In fish, which have more elastic, but less flexible bodies, the structure of the spine differs. The end of each vertebra is a cup containing a viscid fluid, which keeps the bones from approaching nearer to each other than the last state of the elasticity of the lateral ligaments; the fluid is incompressible, therefore forms a ball round which the bony cups move; the ball having no cohesion, the centre of motion is always adapted to the change which the joint undergoes without producing friction.

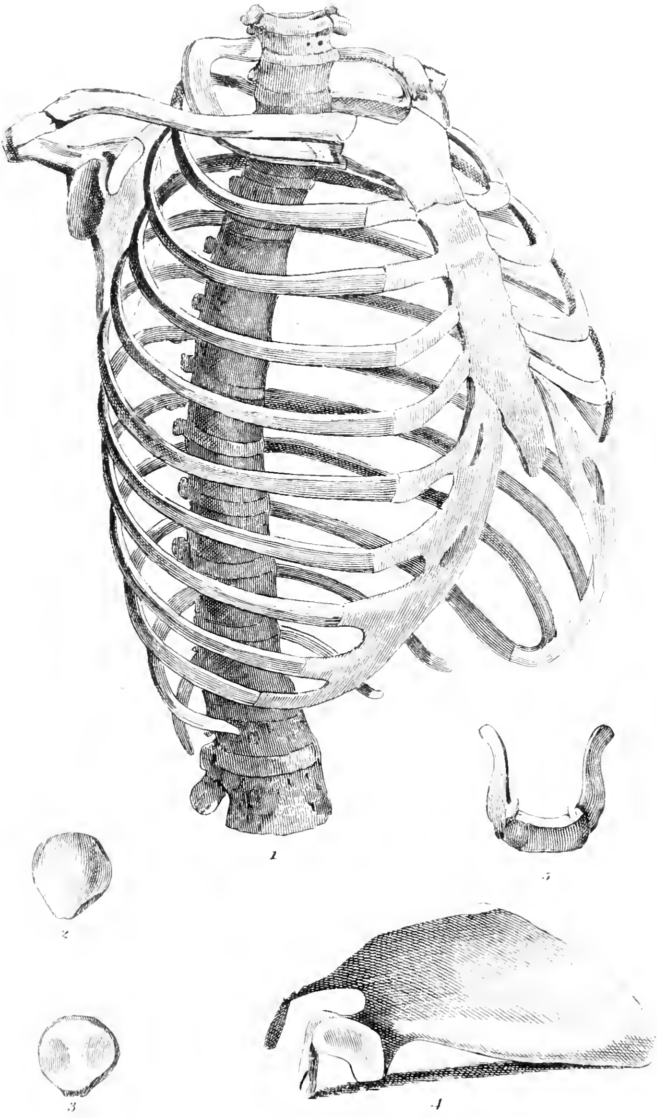
‡ There are fifteen surfaces of articulation to each vertebra.

workmanship in comparison with that of which we speak.

IV. The reciprocal enlargement and contraction of the *chest* to allow for the play of the lungs, depends upon a simple yet beautiful mechanical contrivance, referable to the structure of the bones which enclose it. The ribs are articulated to the back-bone, and to its side projections, *obliquely:* * that is, in their natural position they bend or slope from the place of articulation downwards. But the basis upon which they rest at this end being fixed, the consequence of the obliquity, or the inclination downwards, is, that when they come to move, whatever pulls the ribs upwards, necessarily, at the same time, draws them out; and that, whilst the ribs are brought to a right angle with the spine behind, the sternum, or part of the chest to which they are attached in front, is thrust forward. The simple action, therefore, of the elevating muscles does the business; whereas, if the ribs had been articulated with the bodies of the vertebræ at right angles, the cavity of the thorax could never have been farther enlarged by a change of their position. If each rib had been a rigid bone, articulated at both ends to fixed bases, the whole chest had been immoveable. †

* For the mode of articulation of the ribs with the vertebræ, see TAB. IX. Fig. 1 and 2.

† TAB. X. Fig. 1. The *spine*, *ribs*, and *sternum*, constitute the frame work of the *chest* or *thorax*. Referring, however, to the



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Keill has observed, that the breast-bone, in an easy inspiration, is thrust out one-tenth of an inch: and he calculates that this, added to what is gained to the space within the chest by the flattening or descent of the diaphragm, leaves room for forty-two cubic inches of air to enter at every drawing-in of the breath. When there is a necessity for a deeper and more laborious inspiration, the enlargement of the capacity of the chest may be so increased by effort, as that the lungs may be distended with seventy or a hundred such cubic inches.* The thorax, says Schelhammer, forms a kind of bellows, such as never have been, nor probably will be, made by any artificer.†

V. The *patella*,‡ or knee-pan, is a curious little

plate, or to nature, we observe that the ribs are not continued throughout from the spine to the sternum, but intervening *cartilages* complete the form of the chest, by connecting the end of the first ten ribs to the breast bone. This is a further provision, relative to the mechanical function of the lungs, deserving our attention. The muscles of respiration enlarge the capacity of the chest by elevating the ribs; and, during the momentary interval of muscular action, the cartilages, from their great *elasticity*, restore the ribs to their former position.

* Keill's Anatomy, p. 229.

† Dr. Thompson considers the ordinary quantity of air contained in the lungs is 280 cubic inches, and that there enters into, or goes out, at each inspiration or expiration forty inches. Thus, supposing twenty inspirations in a minute, the quantity of air which would enter and pass out in this time would be 800 inches; which makes 48,000 in the hour, and in twenty-four hours 1,152,000 cubic inches.

‡ Fig. 2. Represents the true shape of the *patella*, the *anterior surface convex*. Fig. 3. the *posterior surface*, which has two *concave* depressions adapted to the condyles of the thigh bone. The projection of the patella, as a lever, or pulley, removes the

bone; in its form and office, unlike any other bone of the body. It is circular: the size of a crown piece; pretty thick; a little convex on both sides, and covered with a smooth cartilage. It lies upon the front of the knee: and the powerful tendons, by which the leg is brought forward, pass into it, (or rather it makes a part of their continuation,) from their origin in the thigh to their insertion in the tibia. It protects both the tendon and the joint from any injury which either might suffer by the rubbing of one against the other, or by the pressure of unequal surfaces. It also gives to the tendons a very considerable mechanical advantage, by altering the line of their direction, and by advancing it farther out from the centre of motion; and this upon the principles of the resolution of force, upon which principles all machinery is founded. These are its uses. But what is most observable in it is, that it appears to be supplemental, as it were, to the frame; added,

acting force from the centre of motion, by which means the muscles have a greater advantage in extending the leg. That this bone is "unlike any other in the body," is a mistake; such bones are numerous, though less obvious, for they do not exceed the size of a pea: these are called *sesamoid bones*, and are formed in the flexor tendons of the thumb, and sometimes in the fingers. They are frequently found under the tendons of some of the muscles. Two of these sort of bones are constantly found under the articulation of the great toe with the foot: some also are discovered, though not so constantly, under the corresponding joints of the other toes. The sesamoid bones, like the patella, remove their tendons from the centre of motion, facilitate their glidings over the bone, and protect their articulations.

as it should almost seem, afterward; not quite necessary, but very convenient. It is separate from the other bones; that is, it is not connected with any other bones by the common mode of union. It is soft, or hardly formed, in infancy; and produced by an ossification, of the inception or progress of which no account can be given from the structure or exercise of the part.

VI. The *shoulder-blade** is, in some material respects, a very singular bone; appearing to be made so expressly for its own purpose, and so independently of every other reason. In such quadrupeds as have no collar-bones, which are by far the greater number, the shoulder-blade has no bony communication with the trunk, either by a joint, or process, or in any other way. It does not grow to, or out of, any other bone of the trunk. It does not apply to any other bone of the trunk; (I know not whether this be true of any second bone in the body, except perhaps the os hyoides:†) in strictness, it forms no part of the skeleton. It is bedded in the flesh; attached

* Fig. 4. This bone (*the scapula*) is joined to the collar bone by ligaments, and to the thorax by powerful muscles which are capable of sustaining immense weights, and whose action gives the various directions to the arm, and enables it freely to revolve at the shoulder joint.

† The *os hyoides* is a small bone situated at the root of the tongue, Fig. 5. It serves as a lever or point for attaching the muscles of the tongue, larynx, and those of deglutition. The figure is introduced as it will be again referred to.

only to the muscles. It is no other than a foundation bone for the arm, laid in separate, as it were, and distinct, from the general ossification. The lower limbs connect themselves at the hip with bones which form part of the skeleton: but this connexion, in the upper limbs, being wanting, a basis, whereupon the arm might be articulated, was to be supplied by a detached ossification for the purpose.

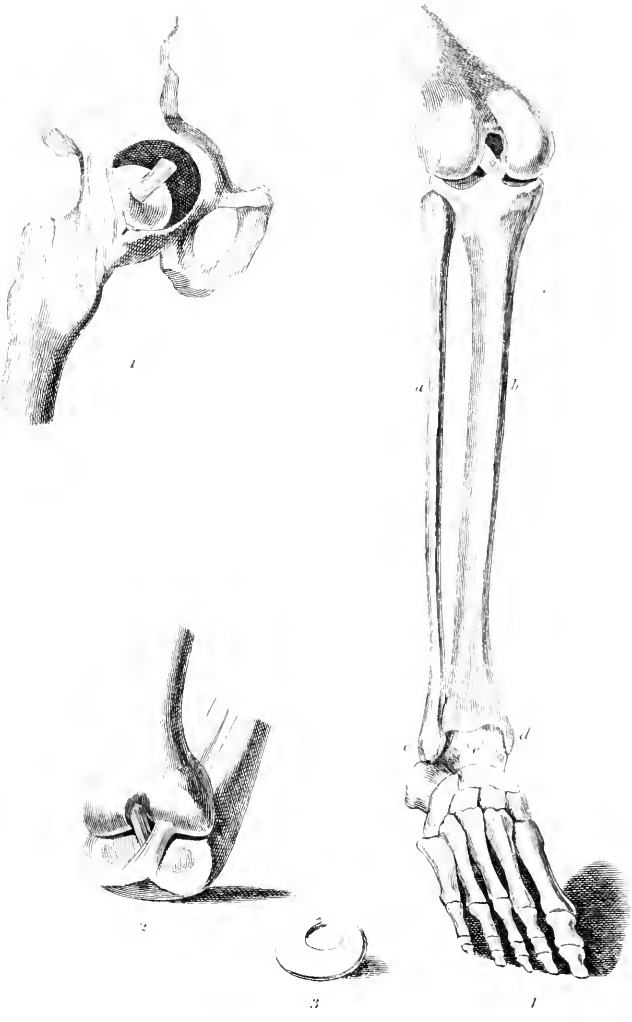
OF THE JOINTS.

I. The above are a few examples of bones made remarkable by their configuration: but to almost all the bones belong *joints;* and in these, still more clearly than in the form or shape of the bones themselves, are seen both contrivance and contriving wisdom. Every joint is a curiosity, and is also strictly mechanical. There is the hinge-joint and the mortice and tenon-joint; each as manifestly such, and as accurately defined, as any which can be produced out of a cabinet-maker's shop; and one or the other prevails, as either is adapted to the motion which is wanted: *e. g.* a mortice and tenon, or ball and socket joint, is not required at the knee, the leg standing in need only of a motion backward and forward in the same plane, for which a hinge-joint is sufficient; a mortice and tenon, or ball and socket joint, is wanted at the hip, that not only the progressive step may be provided for, but the interval between the limbs may be enlarged or contracted at pleasure. Now, observe, what would have been the inconveniency, *i. e.* both the superfluity and the defect of articulation, if the case had been inverted: if the ball and socket joint had been at the knee, and the hinge-joint at the hip. The thighs must have been kept constantly together, and the legs had been loose and straddling. There would have been no use, that we know of, in being able to turn the calves of the legs before; and there would have been great confinement by restraining the motion of the thighs to one plane. The disadvantage would not have been less, if the joints at the hip and the knee had been both of the same sort; both balls and sockets, or both hinges: yet why, independently of utility, and of a Creator who consulted that utility, should the same bone (the thigh-bone) be rounded at one end, and channelled at the other?

The *hinge joint* is not formed by a bolt passing through the two parts of the hinge, and thus keeping them in their places; but by a different expedient. A strong, tough, parchment-like membrane, rising from the receiving bones, and inserted all round the received bones a little below their heads, encloses the joint on every side. This membrane ties, confines, and holds the ends of the bones together; keeping the corresponding parts of the joint, *i. e.* the relative convexities and concavities, in close application to each other.*

For the *ball and socket joint*, beside the membrane already described, there is in one important joint, as an additional security, a short, strong, yet flexible ligament, inserted by one end into the head of the ball, by the other into the bottom of the cup; which ligament keeps the two parts of the joint so firmly in their place, that none of the motions which the limb naturally performs, none of the jerks and twists to which it is ordinarily liable, nothing less indeed than the utmost and the most unnatural violence, can pull them asunder. It is hardly imaginable, how great a force is necessary, even to stretch, still more to break, this ligament; yet so flexible is it, as to oppose no impediment to the suppleness of the joint. By its situation also, it is inaccessible to injury from sharp edges. As it cannot be ruptured, (such is its strength,) so it cannot be cut, except by an accident which would sever the limb. If I had been permitted to frame a proof

* This membrane is the *capsular*, or *bursal ligament*, common to every moveable joint. It certainly connects the bones together, but does not possess much strength; its chief use is to produce and preserve the synovia in the part where it is required. The security and strength of the hinge joint depends on certain ligaments called lateral ligaments, and the tendons of those muscles which pass over it. In the particular instance of the knee, from its being the largest joint in the body, there is, as we shall presently find, an additional contrivance to prevent dislocation.



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of contrivance, such as might satisfy the most distrustful inquirer, I know not whether I could have chosen an example of mechanism more unequivocal, or more free from objection, than this ligament. Nothing can be more mechanical; nothing, however subservient to the safety, less capable of being generated by the action of the joint. I would particularly solicit the reader's attention to this provision, which is found in the head of the *thigh-bone;** to its strength, its structure, and its use. It is an instance upon which I lay my hand. One single fact, weighed by a mind in earnest, leaves oftentimes the deepest impression. For the purpose of addressing different understandings and different apprehensions—for the purpose of sentiment, for the purpose of exciting admiration of the Creator's works, we diversify our views, we multiply examples; but for the purpose of strict argument, one clear instance is sufficient; and not only sufficient, but capable perhaps of generating a firmer assurance than what can arise from a divided attention.

The *ginglymus*, or hinge joint, does not, it is

* Tab. XI. Fig. 1. The capsular ligament is here opened in order to shew the ligament of the hip, named the *round ligament*. It allows considerable latitude of motion, at the same time that it is the great safe-guard against dislocation. This ligament is also common to all quadrupeds, even in the more large and unwieldly, as the Hippopotamus and Rhinoceros—it is wanting in the Elephant only, whose limbs, ill qualified for active movements, do not seem to require this security to the joint.

manifest, admit of a ligament of the same kind with that of the ball and socket joint, but it is always fortified by the species of ligament of which it does admit. The strong, firm, investing membrane, above described, accompanies it in every part; and in particular joints, this membrane, which is properly a ligament, is considerably stronger on the sides than either before or behind,* in order that the convexities may play true in their concavities, and not be subject to slip sideways, which is the chief danger; for the muscular tendons generally restrain the parts from going farther than they ought to go in the plane of their motion. In the *knee*, which is a joint of this form, and of great importance, there are superadded to the common provisions for the stability of the joint, two strong ligaments which cross each other; and cross each other in such a manner, as to secure the joint from being displaced in any assignable direction.† "I think," says Cheselden,

* The sides of hinge joints are always strengthened by *lateral ligaments,* distinct from the capsular, the use of which is correctly stated.

† Fig. 2. and 4. the *crucial* or *internal ligaments* of the knee-joint arise from each side of the depression between the condyles of the thigh bone; the anterior is fixed into the centre, the posterior into the back of the articulation of the tibia. This structure properly limits the motions of the joint, and gives the firmness requisite for violent exertions. Viewing the form of the bones, we should consider it one of the weakest and most superficial, but the strength of its ligaments and the tendons passing over it renders it the most secure, and the least liable to dislocation of any joint in the whole body.

"that the knee cannot be completely dislocated without breaking the *cross* ligaments."* We can hardly help comparing this with the binding up of a fracture, where the fillet is almost always strapped across, for the sake of giving firmness and strength to the bandage.

Another no less important joint, and that also of the ginglymus sort, is the *ankle;* yet, though important, (in order, perhaps, to preserve the symmetry and lightness of the limb,) *small*, and, on that account more likely to injury. Now this joint is strengthened, *i. e.* is defended from dislocation, by two remarkable processes or prolongations of the bones of the leg: which processes form the protuberances that we call the inner and outer ankle. It is part of each bone going down lower than the other part, and thereby overlapping the joint: so that, if the joint be in danger of slipping outward, it is curbed by the inner projection, *i. e.* that of the tibia; if inward, by the outer projection, *i. e.* that of the fibula. Between both, it is locked in its position. I know no account that can be given of this structure, except its utility. Why should the tibia terminate, at its lower extremity, with a double end, and the fibula the same—but to barricade the joints on both sides by a continuation of part of the thickest of the bone over it?† The joint at the *shoulder* compared

* Cheselden's Anatomy. p. 45. edit. 7.

† Fig. 4. *a*, the *fibula;* *b*, the *tibia*, the lower extremities of

with the joint at the *hip*, though both ball and socket joints, discovers a difference in their form and proportions, well suited to the different offices which the limbs have to execute. The cup or socket at the shoulder is much shallower and flatter than it is at the hip, and is also in part formed of cartilage set round the rim of the cup. The socket, into which the head of the thigh-bone is inserted, is deeper, and made of more solid materials.* This agrees with the duties assigned to each part. The arm is an instrument of motion, principally, if not solely. Accordingly the shallowness of the socket at the shoulder, and yieldingness of the cartilaginous substance with which its edge is set round, and which in fact composes a considerable part of its concavity, are excellently adapted for the allowance of a free motion and a wide range; both which the arm wants. Whereas, the lower limb, forming a part of the column of the body; having to support the body, as well as to be the means of its locomo-

which, *e*, *d*, form the outer and inner ankle, and receive, *e*, the great articulating bone of the foot, called the astragalus between them. When the foot sustains the weight of the body the joint is firm, but when raised it easily rolls on the ends of these bones, so that the toe is directed to the place on which we intend to step.

* The socket for the head of the thigh-bone is indeed deeper than that at the shoulder, but the "materials" which form the concavities are the same; both are solid bone covered by cartilages and both have a rim of a strong fibro-cartilaginous texture, not only for the purpose of rendering the socket deeper, but for preventing fractures of the rim in robust exercises, to which, were it bony, it would be very liable.

tion; firmness was to be consulted, as well as action. With a capacity for motion, in all directions indeed, as at the shoulder, but not in any direction to the same extent as in the arm, was to be united stability, or resistance to dislocation. Hence the deeper excavation of the socket; and the presence of a less proportion of cartilage upon the edge.

The suppleness and pliability of the joints we every moment experience; and the *firmness* of animal articulation, the property we have hitherto been considering, may be judged of from this single observation, that, at any given moment of time, there are millions of animal joints in complete repair and use, for one that is dislocated; and this, notwithstanding the contortions and wrenches to which the limbs of animals are continually subject.

II. The *joints*, or rather the ends of the bones which form them, display also, in their configuration, another use. The nerves, blood-vessels, and tendons, which are necessary to the life, or for the motion of the limbs, must, it is evident, in their way from the trunk of the body to the place of their destination, travel over the moveable joints; and it is no less evident, that, in this part of their course, they will have, from sudden motions, and from abrupt changes of curvature, to encounter the danger of compression, attrition, or laceration. To guard fibres so tender against consequences so injurious, their path is in those parts protected with peculiar care; and that by a provision in the figure of the bones themselves. The nerves which supply the *fore-arm*, especially the inferior cubital nerves, are at the elbow conducted, by a kind of covered way, between the condyles, or rather under the inner extuberances of the bone, which composes the upper part of the arm.* At the *knee*, the extremity of the thigh-bone is divided by a sinus or cleft into two heads or protuberances: and these heads on the back part stand out beyond the cylinder of the bone. Through the hollow, which lies between the hind-parts of these two heads, that is to say, under the ham, between the hamstrings, and within the concave recess of the bone formed by the extuberances on each side; in a word, along a defile, between rocks, pass the great vessels and nerves which go to the leg.† Who led these vessels by a road so defended and secured? In the joint at the *shoulder*, in the edge of the cup which receives the head of the bone, is a *notch*,‡ which is joined or covered at the top with a ligament. Through this hole, thus guarded, the

* Cheselden's Anatomy, p. 255. edit. 7.

In many animals the nerves of the fore leg, which correspond with these nerves, for their protection are actually conducted through a hole in the bone.

† Cheselden's Anatomy, p, 35. edit. 7.

‡ This is called the *semilunar notch*; it is not "in the edge of the cup," but on the superior border near to it. A ligament extends from one point of the notch to the other, forming a foramen, which is traversed by the superior scapular, nerves, and blood-vessels.

blood-vessels steal to their destination in the arm, instead of mounting over the edge of the concavity.*

III. In all joints, the ends of the bones, which work against each other, are tipped with *gristle*. In the ball and socket joint, the cup is lined, and the ball capped with it. The smooth surface, the elastic and unfriable nature of cartilage, render it of all substances the most proper for the place and purpose. I should, therefore, have pointed this out amongst the foremost of the provisions which have been made in the joints for the facilitating of their action, had it not been alleged, that cartilage in truth is only nascent or imperfect bone; and that the bone in these places is kept soft and imperfect, in consequence of a more complete and rigid ossification being prevented from taking place by the continual motion and rubbing of the surfaces; which being so, what we represent as a designed advantage, is an unavoidable effect. I am far from being convinced that this is a true account of the fact; or that, if it were so, it answers the argument. To me, the surmounting of the ends of the bones with gristle, looks more like a plating with a different metal, than like the same metal kept in a different state by the action to which it is exposed.† At all events, we have a great particular

* Cheselden's Anatomy, p. 30. edit. 7.

† *Cartilage* is of a white or pearly colour, elastic and softer than bone, from having a smaller quantity of earth in its composition.

benefit, though arising from a general constitution: but this last not being quite what my argument requires, lest I should seem by applying the instance to overrate its value, I have thought it fair to state the question which attends it.

IV. In some joints, very particularly in the knees, there are loose cartilages or gristles between the bones, and within the joint, so that the ends of the bones, instead of working upon one another, work upon the intermediate cartilages.* Cheselden has observed† that the contrivance of a loose ring is practised by mechanics, where the friction of the joints of any of their machines is great; as between the parts of crook-hinges of large gates,

It posesses neither nerves nor blood-vessels, at least in a sound adult state none can be demonstrated; and having no sensibility, it is a material eminently fitted for the compression and friction it is perpetually undergoing. Where the motion is confined, the cartilage firmly unites bones, as, for instance, the ribs to the breast bone.

* Fig. 3. one of the *interarticular* cartilages of the knee, from their shape called *semilunar*; it is also represented *in situ* Fig. 2. The outer edge of each cartilage is thick, the inner concave edge thin; the sockets for the condyles of the thigh-bone are thus rendered deeper, and the cartilages are so fixed as to allow a little play on the tibia. Another use which has been assigned to them is that of cushions, which, giving way to pressure, again recover their form, and protect the articular surfaces to which they correspond.

A moving cartilage is not common but is peculiar to those joints whose motions are very frequent, or which move under a great weight. It is a contrivance found at the jaw, the inner head of the collar bone, and the articulation of the wrist, as well as at the knee. The obvious use is to lesson friction and facilitate motion.

† Cheselden's Anatomy, p. 13. edit.7.

or under the head of the male screw of large vices. The cartilages of which we speak, have very much of the form of these rings. The comparison moreover shows the reason why we find them in the knees rather than in other joints. It is an expedient, we have seen, which a mechanic resorts to, only when some strong and heavy work is to be done. So here the thigh-bone has to achieve its motion at the knee, with the whole weight of the body pressing upon it, and often, as in rising from our seat, with the whole weight of the body to lift. It should seem also, from Cheselden's account, that the slipping and sliding of the loose cartilages, though it be probably a small and obscure change, humoured the motion of the end of the thigh-bone, under the particular configuration which was necessary to be given to it for the commodious action of the tendons; (and which configuration requires what he calls a variable socket, that is, a concavity, the lines of which assume a different curvature in different inclinations of the bones.)

V. We have now done with the configuration: but there is also in the joints, and that common to them all, another exquisite provision, manifestly adapted to their use, and concerning which there can, I think, be no dispute, namely, the regular supply of a *mucilage*, more emollient and slippery than oil itself, which is constantly softening and lubricating the parts that rub upon each other, and thereby diminishing the effect of attrition in the highest possible degree.* For the continual secretion of this important liniment, and for the feeding of the cavities of the joint with it, glands are fixed near each joint; the excretory ducts of which glands dripping with their balsamic contents, hang loose like fringes within the cavity of the joints. A late improvement in what are called friction-wheels, which consist of a mechanism so ordered, as to be regularly dropping oil into a box, which encloses the axis, the nave, and certain balls upon which the nave revolves, may be said, in some sort, to represent the contrivance in the animal joint; with this superiority, however, on the part of the joint, viz. that here, the oil is not only dropped, but *made*.†

In considering the joints, there is nothing, perhaps, which ought to move our gratitude more

* This mucilage is termed *synovia;* vulgarly called joint oil, but it has no property of oil. It is very viscid, and at the same time smooth and slippery to the touch; and therefore better adapted than any oil to lubricate the interior of the joints and prevent ill effects from friction.

† From this interesting description a very correct idea may be formed of the apparatus termed *bursæ mucosæ.* These are *masses of fat* found in the greater number of joints, covered with a continuation of the inner layer of the capsular ligament, and projecting in such a manner as to receive gentle pressure from the motions of the joint; and in proportion to the frequency of the motion the fluid which the bursæ secrete is supplied in a greater or less quantity. From the edges of these bodies there are *fimbriæ* which convey the synovia into the cavity of the joint. This contrivance is found not only in joints, but between other parts exposed to friction, as between *tendons* and *bones*, where they play on each other.

than the reflection, *how well they wear.* A limb shall swing upon its hinge, or play in its socket, many hundred times in an hour, for sixty years together, without diminution of its agility: which is a long time for any thing to last; for any thing so much worked and exercised as the joints are. This durability I should attribute, in part, to the provision which is made for preventing of wear and tear, first by the polish of the cartilaginous surfaces; secondly, by the healing lubrication of the mucilage; and, in part, to that astonishing property of animal constitutions, assimilation; by which, in every portion of the body, let it consist of what it will, substance is restored, and waste repaired.*

Moveable joints, I think, compose the curiosity of bones; but their union, even where no motion is intended or wanted, carries marks of mechanism and of mechanical wisdom. The teeth, especially the front teeth, are one bone fixed in another, like a peg driven into a board. The sutures of the skull are like the edges of two saws clapped together, in such a manner as that the teeth of one enter the intervals of the other.† We have some-

* There is waste in the animal system but not wear; for as the structure of the parts is originally perfected by the action of the vessels, "the function or operation of the part is made the stimulus to those vessels. The cuticle of the hands wears away like a glove; but the pressure stimulates the living surface to force successive layers of skin under that which is wearing."

† Most of the bones of the skull are composed of two plates or

times one bone lapping over another, and planed down at the edges; sometimes also the thin lamella of one bone received into a narrow furrow of another. In all which varieties, we seem to discover the same design, viz. firmness of juncture, without clumsiness in the seam.

CHAPTER IX.

OF THE MUSCLES.

Muscles, with their tendons, are the instruments by which animal motion is performed. It

tablets, with an intermediate spongy vascular substance: the outer tablet is *fibrous*, having the edges curiously indented and united by a *dove-tailed* suture; the inner from its brittleness is called *vitreous*, and therefore merely joined together in a straight line; this mode of union is not accidental—not the result of chance, but design. The author of the treatise on "Animal Mechanics" gives the following admirable illustration of the structure:—

"Suppose a carpenter employed upon his own material—he would join a box with regular indentations by dove-tailing, because he knows that the material on which he works, from its softness and toughness, admits of such adjustment of its edges. The processes of bone shoot into the opposite cavities with an exact resemblance to the fox-tail wedge of the carpenter.

"But if a workman in glass or marble were to join these materials, he would smooth the edges and unite them by cement; for if he could succeed in indenting the line of union, he knows that his material would chip off on the slightest vibration.

"Now apply this principle to the skull; the outer table, which resembles wood, is indented and dove-tailed; the inner glassy table has its edges simply laid in contact."

will be our business to point out instances in which, and properties with respect to which, the disposition of these muscles is as strictly mechanical, as that of the wires and strings of a puppet.*

I. We may observe, what I believe is universal, an exact relation between the joint and the muscles which move it. Whatever motion the joint, by its mechanical construction, is capable of performing, that motion, the annexed muscles, by their position, are capable of producing. For example; if there be, as at the knee and elbow, a hinge joint, capable of motion only in the same plane, the leaders, as they are called, *i. e.* the muscular tendons, are placed in directions parallel to the bone, so as, by the contraction or relaxation of the muscles to which they belong, to produce that motion and no other. If these joints were capable of a freer motion, there are no muscles to produce it. Whereas at the shoulder and the hip, where the ball and socket joint allows by its construction of a rotatory or sweeping motion, tendons are placed in such a position, and pull in such a direction, as to produce the motion of which the joint

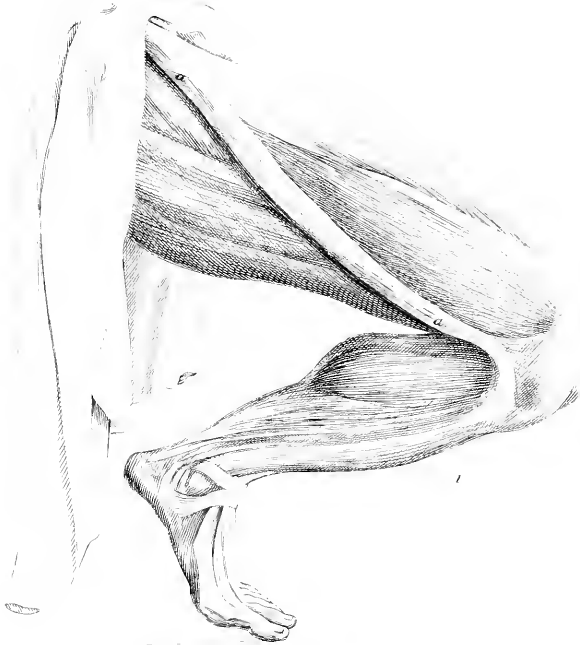
* Muscles are the *fleshy* parts of the body which surround the bones, having a fibrous texture; a muscle being composed of a number of *muscular faciculi*, which are composed of fibres still smaller; these result from fibres of a less volume, until by successive division we arrive at very small fibres no longer divisible. These muscular fibres are longer or shorter according to the muscles to which they belong; and every fibre is fixed by its two extremities to *tendon* or *aponeurosis*, which are the "wires and strings" which conduct the muscular power when they contract.

admits. For instance, the sartorius or tailor's muscle, rising from the spine,* running diagonally across the thigh, and taking hold of the inside of the main bone of the leg, a little below the knee, enables us, by its contraction, to throw one leg and thigh over the other; giving effect, at the same time, to the ball and socket joint at the hip, and the hinge joint at the knee.† There is, as we have seen, a specific mechanism in the bones, for the rotatory motions of the head and hands; there is, also, in the oblique direction of the muscles belonging to them, a specific provision for the putting of this mechanism of the bones into action. And mark the consent of uses. The oblique muscles would have been inefficient without that particular articulation; that particular articulation would have been lost, without the oblique muscles. It may be proper, however, to observe with respect to the *head*, although I think it does not vary the case, that its oblique motions and inclinations are often motions in a *diagonal*, produced by the joint action of muscles lying in straight direction. But whether the pull be single or combined, the articulation is always such, as to be capable of obeying the action of the muscles. The oblique muscles attached to the head, are like-

* This should read, " The front upper spine of the hip bone."

† Tab. XII. Fig. 1. *a*, *a*, the *sartorius*, is the longest muscle of the whole fabric: it is extended obliquely across the thigh from the fore part of the hip to the inner side of the tibia. Its office is to bend the knee and bring the leg inwards.

TAB. XII



wise so disposed, as to be capable of steadying the globe, as well as of moving it.* The head of a newborn infant is often obliged to be filleted up. After death, the head drops and rolls in every direction. So that it is by the equilibre of the muscles, by the aid of a considerable and equipollent muscular force in constant exertion, that the head maintains its erect posture. The muscles here supply what would otherwise be a great defect in the articulation; for the joint in the neck, although admirably adapted to the motion of the head, is insufficient for its support. It is not only by the means of a most curious structure of the bones that a man turns his head, but by virtue of an adjusted muscular power, that he even holds it up.

As another example of what we are illustrating, viz. conformity of use between the bones and the muscles, it has been observed of the different vertebræ, that their processes are exactly proportioned to the quantity of motion which the other bones allow of, and which the respective muscles are capable of producing.

II. A muscle acts only by contraction.† Its

* There are two pairs of oblique muscles; Fig. 2. *a, a*, the *obliquus capitis superior*, arising from the transverse process of the atlas, and inserted into the occipital bone; *b, b*, the *obliquus capitis inferior*, arising from the spinous process of the dentata, and inserted into the transverse process of the atlas. These muscles roll the head on one side and draw it backwards.

† The muscular fibres are parallel and straight, if the muscle be in a state of repose; but when the muscle contracts, immediately the fibres bend themselves into a zigzag direction, and present a

force is exerted in no other way. When the exertion ceases, it relaxes itself, that is, it returns by relaxation to its former state; but without energy. This is the nature of the muscular fibre: and being so, it is evident that the reciprocal *energetic* motion of the limbs, by which we mean motion *with force* in opposite directions, can only be produced by the instrumentality of opposite or antagonist muscles; of flexors and extensors answering to each other. For instance, the biceps and brachiæus *internus** muscles, placed in the front part of the upper arm, by their contraction bend the elbow; and with such degree of force, as the case requires, or the strength admits of. The relaxation of these muscles, after the effort, would merely let the fore-arm drop down. For the *back stroke*, therefore, and that the arm may not only bend at the elbow, but also extend and straighten itself, with force, other muscles, the longus and brevis brachiæus *externus*† and the

number of angular and regularly opposed undulations. Muscular action is under the influence of the brain and nerves; if the brain of a man or animal is compressed, the faculty of contracting the muscle ceases; the nerves of a muscle being cut, it loses all power.

* Tab. XIII. Fig. 1. *a*, the *biceps* (biceps flexor cubiti) arise by two portions from the scapula; they form a thick mass of flesh in the middle of the arm, which is finally inserted into the upper end of the radius; *b*, the *brachiæus internus*, arises from the middle of the *os humeri*, and is inserted into the ulna. Both these muscles bend the fore-arm.

† *e*, the *longus et brevis brachiæus externus*, better named as one muscle, *triceps extensor cubiti*. It is attached to the inferior

TAB. XIII.

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anconæus,* placed on the hinder part of the arms, by their contractile twitch fetch back the fore-arm into a straight line with the cubit, with no less force than that with which it was bent out of it. The same thing obtains in all the limbs, and in every moveable part of the body. A finger is not bent and straightened, without the *contraction* of two muscles taking place.* It is evident, therefore, that the animal functions require that particular disposition of the muscles which we describe by the name of antagonist muscles. And they are accordingly so disposed. Every muscle is provided with an adversary. They act, like two sawyers in a pit, by an opposite pull; and nothing surely can more strongly indicate design and attention to an end, than their being thus stationed, than this collocation. The nature of the muscular fibre being what it is, the purposes of the animal could be answered by no other. And not only the capacity for motion, but the aspect and symmetry of the body, is preserved by the muscles being marshalled according to this

edge of the scapula, and to the os humeri, by three distinct heads, which unite and invest the whole back part of the bone; which, becoming a strong tendon, is implanted into the elbow. It is a powerful extensor of the fore-arm.

* *d*, the *anconæus*, a small triangular muscle, situated at the outer side of the elbow; it assists the last muscle.

† *Four* muscles are concerned in producing every such movement of the finger, viz. in bending the finger the *flexor sublimis, flexor profundus*, and *lumbricus* contract; in again bringing it into the straight position, the *extensor* muscle is called into action.

order; *e. g.* the mouth is holden in the middle of the face, and its angles kept in a state of exact correspondency, by several muscles drawing against, and balancing each other.* In a hemiplegia,† when the muscles on one side are weakened, the muscles on the other side draw the mouth away.

III. Another property of the muscles, which could only be the result of care, is, their being almost universally so disposed, as not to obstruct or interfere with one another's action. I know but one instance in which this impediment is perceived. We cannot easily swallow whilst we gape. This, I understand, is owing to the muscles employed in the act of deglutition being so implicated with the muscles of the lower jaw, that, whilst these last are contracted, the former cannot act with freedom. The obstruction is, in this instance, attended with little inconveniency; but it shows what the effect is where it does exist; and what loss of faculty there would be if it were more frequent. Now, when we reflect upon the number of muscles, not fewer than four hundred and forty-six in the human body, known and named,‡ how contiguous they lie to each other, in layers, as it were, over one another, crossing one another, sometimes imbedded in one another; sometimes

* See Tab. XIV. Fig. 3.

† A paralytic affection of one side of the body.

‡ There are five hundred and twenty-seven muscles described by more modern anatomists.

perforating one another; an arrangement, which leaves to each its liberty, and its full play, must necessarily require meditation and counsel.

IV. The following is oftentimes the case with the muscles. Their action is wanted, where their situation would be inconvenient. In which case, the body of the muscle is placed in some commodious position at a distance, and made to communicate with the point of action, by slender strings or wires. If the muscles which move the fingers, had been placed in the palm or back of the hand, they would have swelled that part to an awkward and clumsy thickness. The beauty, the proportions of the part, would have been destroyed. They are, therefore, disposed in the arm, and even up to the elbow; and act by long tendons, strapped down at the wrist, and passing under the ligaments to the fingers, and to the joints of the fingers, which they are severally to move.* In like manner, the muscles which move the toes, and many of the joints of the foot, how gracefully are they disposed in the calf of the leg, instead of forming an unwieldly tumefaction in the foot itself! The observation may be repeated of the muscle which draws the nictitating membrane over the eye. Its office is in the front of the eye; but its body is

* See Tab. XIII. Fig. 1 and 2. *e, e,* the *annular ligament* of the wrist, under which pass the tendons of the muscles of the fingers.

lodged in the back part of the globe, where it lies safe, and were it encumbers nothing.*

V. The great mechanical variety in the figure of the muscles may be thus stated. It appears to be a fixed law, that the contraction of a muscle shall be towards its centre. Therefore, the subject for mechanism on each occasion is, so to modify the figure, and adjust the position of the muscle, as to produce the motion required, agreeably with this law. This can only be done by giving to different muscles a diversity of configuration, suited to their several offices, and to their situation with respect to the work which they have to perform. On which account we find them under a multiplicity of forms and attitudes; sometimes with double, sometimes with treble tendons, sometimes with none: sometimes one tendon to several muscles, at other times one muscle to several tendons. The shape of the organ is susceptible of an incalculable variety,

* See TAB. IV. Fig. 2 and 3. The convenience and beauty of the tendons seem only an ulterior object, their necessity and utility principally claim our attention. The force which a muscle possesses is as the number of the muscular fibres; but a limited number of fibres only can be fixed to any certain point of bone destined to be moved, therefore the contrivance is, to attach them to a cord, called a sinew or tendon, which can be conveniently conducted and fixed to the bone. If we are desirous of moving a heavy weight, we tie a strong cord to it, that a greater number of men may apply their strength. Thus a similar effect is produced—the muscular fibres are the moving powers, the tendons are the cords attached to the point to be moved.

whilst the original property of the muscle, the law and line of its contraction, remains the same, and is simple.* Herein the muscular system may be said to bear a perfect resemblance to our works of art. An artist does not alter the native quality of his materials or their laws of action. He takes these as he finds them. His skill and ingenuity are employed in turning them, such as they are, to his account, by giving to the parts of his machine a form and relation, in which these unalterable properties may operate to the production of the effects intended.

VI. The ejaculations can never too often be repeated:—How many things must go right for us to be an hour at ease! how many more for us to be vigorous and active! Yet vigour and activity are, in a vast plurality of instances, preserved in human bodies, notwithstanding that they depend upon so great a number of instruments of motion, and notwithstanding that the defect or disorder sometimes of a very small instrument, of a single pair, for instance, out of the four hundred and forty-six muscles which are employed, may be attended with grievous inconveniency. There is

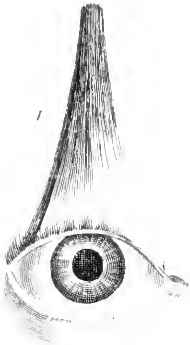
* A good idea of the varied forms of the muscular system may be obtained by consulting Cowper's *Myotomia Reformata*, wherein are accurate figures of each detached muscle. The splendid folio of Albinus contains fine engravings of the bones and muscles; but there is no book which we have more gratification in recommending than the admirable work of M. Jules Cloquet, the *Anatomie de l'Homme*.

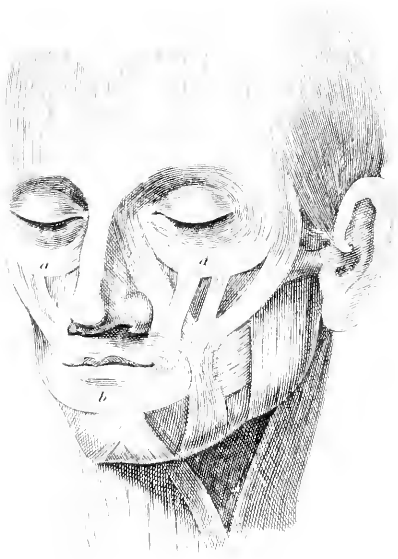
piety and good sense in the following observation, taken out of the *Religious Philosopher:* "With much compassion," says this writer, "as well as astonishment at the goodness of our loving Creator, have I considered the sad state of a certain gentleman, who, as to the rest, was in pretty good health, but only wanted the use of these *two little muscles* that serve to lift up the eyelids, and so had almost lost the use of his sight, being forced, as long as this defect lasted, to shove up his eyelids every moment with his own hands!"* In general we may remark, in how small a degree those who enjoy the perfect use of their organs, know the comprehensiveness of the blessing, the variety of their obligation. They perceive a result, but they think little of the multitude of concurrences and rectitudes which go to form it.

Besides these observations, which belong to the muscular organ as such, we may notice some advantages of structure, which are more conspicuous in muscles of a certain class or description than in others. Thus:

I. The variety, quickness, and precision, of which muscular motion is capable, are seen, I think, in no part so remarkably as in the *tongue.* It is worth any man's while to watch the agility

* Tab. XIV. Fig. 1. A front view of this muscle named *levator palpebræ superioris:* Fig. 2. a profile of the same in its natural position. This muscle arises within the orbit, and is inserted by a broad tendon into the upper eye-lid. Its name is expressive of the use.





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of his tongue; the wonderful promptitude with which it executes changes of position, and the perfect exactness. Each syllable of articulated sound requires for its utterance a specific action of the tongue, and of the parts adjacent to it. The disposition and configuration of the mouth, appertaining to every letter and word, is not only peculiar, but, if nicely and accurately attended to, perceptible to the sight; insomuch, that curious persons have availed themselves of this circumstance to teach the deaf to speak, and to understand what is said by others. In the same person, and after his habit of speaking is formed, one and only one, position of the parts, will produce a given articulate sound correctly. How instantaneously are these positions assumed and dismissed! how numerous are the permutations, how various, yet how infallible! Arbitrary and antic variety is not the thing we admire; but variety obeying a rule, conducing to an effect, and commensurate with exigencies infinitely diversified. I believe also that the anatomy of the tongue corresponds with these observations upon its activity. The muscles of the tongue are so numerous and so implicated with one another, that they cannot be traced by the nicest dissection;* nevertheless

* For performing its varied movements, the tongue is provided with *four* regular pairs of muscles, besides sets of short muscular fibres called *fibræ longitudinales transversæ;* and *perpendiculares:* these are the intricate fibres referred to; they cannot be separated, being so much involved in the adjacent muscles.

(which is a great perfection of the organ,) neither the number, nor the complexity, nor what might seem to be the entanglement of its fibres, in any wise impede its motion, or render the determination or success of its efforts uncertain.

I here entreat the reader's permission to step a little out of my way, to consider *the parts of the mouth*, in some of their other properties. It has been said, and that by an eminent physiologist, that, whenever nature attempts to work two or more purposes by one instrument, she does both or all imperfectly. Is this true of the tongue, regarded as an instrument of speech, and of taste; or regarded as an instrument of speech, of taste, and of deglutition? So much otherwise, that many persons, that is to say, nine hundred and ninety-nine persons out of a thousand, by the instrumentality of this one organ, talk, and taste, and swallow, very well. In fact, the constant warmth and moisture of the tongue, the thinness of the skin, the papillæ upon its surface, qualify this organ for its office of tasting, as much as its inextricable multiplicity of fibres do for the rapid movements which are necessary to speech. Animals which feed upon grass, have their tongues covered with a perforated skin, so as to admit the dissolved food to the papillæ underneath, which, in the mean time, remain defended from the rough action of the unbruised spiculæ.*

* *Papillæ* are small bodies situated on the surface and sides of

There are brought together within the cavity of the mouth more distinct uses, and parts executing more distinct offices, than I think can be found lying so near to one another, or within the same compass, in any other portion of the body: viz. teeth of different shape, first for cutting; secondly for grinding:* muscles, most artificially disposed for carrying on the compound motion of the lower jaw, half lateral and half vertical, by which the mill is worked:† fountains of saliva, springing up in different parts of the cavity for the moistening of the food, whilst the mastication is going on:

the tongue; they are furnished by the extreme filaments of the gustatory nerve, through which medium we acquire the sense of tasting.

In herbivorous animals the papillæ are sharp pointed and directed backwards to assist in laying hold of the grass. In the cat kind there is a horny or prickly set covering the tongue, rendering it rough and enabling it to take firmer hold of the prey. Birds also have a similar contrivance. In fish the tongue is covered by a number of teeth, serving the same purpose.

* In each jaw there are *four incisores*, or cutting teeth, *two canine* which may be ranked with the former, only more pointed; —four small *molar*, and six large molar or grinding teeth. And as the teeth of animals indicate the food on which they are destined to subsist, so from analogy we may infer that man is called to use either animal or vegetable aliments, or both, i. e. keeps a mean between graminivorous and carnivorous animals, in the structure and complication of his digestive apparatus, without deserving on that account to be called omnivorous: for it is known, that, a great number of the substances upon which animals feed are of no use in the support of man.

† Mastication requiring muscles of great power; there are two temporal, two masseter, and four pterygoid muscles; these have great strength, especially the first two pairs, which draw the jaw upwards; the latter move the jaw horizontally in the act of grinding our food.

glands,* to feed the fountains; a muscular constriction of a very peculiar kind in the back part of the cavity, for the guiding of the prepared aliment into its passage towards the stomach, and in many cases for carrying it along that passage; for, although we may imagine this to be done simply by the weight of the food itself, it in truth is not so, even in the upright posture of the human neck; and most evidently is not the case with quadrupeds, with a horse for instance, in which when pasturing, the food is thrust upward by muscular strength, instead of descending of its own accord.†

In the mean time, and within the same cavity, is going on another business, altogether different from what is here described—that of respiration and speech. In addition therefore to all that has been mentioned, we have a passage opened, from this cavity to the lungs, for the admission of air, exclusively of every other substance; we have muscles, some in the larynx, and without number in the tongue, for the purpose of modulating that air in its passage, with a variety, a compass, and

* The principal of these are the *parotids*, see TAB. XX. There are others; *the submaxillary* under the jaw, and those under the tongue called the *sublingual;* food, or sometimes even hunger, causes an afflux of saliva from these glands into the mouth.

† There are three pairs of muscles of the *pharynx*, or upper part of this passage; their action is, when stimulated by food, to propel it into the *œsophagus*, a strong fleshy canal, the muscular fibres of which contract in succession, and force the contents of the tube into the stomach.

precision, of which no other musical instrument is capable. And, lastly, which in my opinion crowns the whole as a piece of machinery, we have a specific contrivance for dividing the pneumatic part from the mechanical, and for preventing one set of actions interfering with the other.* Where various functions are united, the difficulty is to guard against the inconveniences of a too great complexity. In no apparatus put together by art, and for the purposes of art, do I know such multifarious uses so aptly combined, as in the natural organization of the human mouth; or, where the structure, compared with the uses, is so simple. The mouth, with all these intentions to serve, is a single cavity; is one machine, with its parts neither crowded nor confused, and each unembarrassed by the rest: each at least at liberty in a degree sufficient for the end to be attained. If we cannot eat and sing at the same moment, we can eat one moment and sing the next; the respiration proceeding freely all the while.

There is one case however of this double office, and that of the *earliest* necessity, which the mouth alone could not perform; and that is, carrying on together the two actions of sucking and breathing. Another route therefore is opened for the air, namely, through the nose, which lets the breath pass backward and forward, whilst the lips, in the act of sucking, are necessarily shut close upon the

* See Tab. XXI.

body from which the nutriment is drawn. This is a circumstance which always appeared to me worthy of notice. The nose would have been necessary, although it had not been the organ of smelling. The making it a seat of a sense, was superadding a new use to a part already wanted; was taking a wise advantage of an antecedent and a constitutional necessity.*

But to return to that which is the proper subject of the present section—the celerity and precision of muscular motion. These qualities may be particularly observed in the execution of many pieces of instrumental *music*, in which the changes produced by the hand of the musician are exceedingly rapid; are exactly measured, even when most minute; and display, on the part of the muscles, an obedience of action, alike wonderful for its quickness and its correctness.

Or let a person only observe his own hand whilst he is *writing*; the number of muscles which are brought to bear upon the pen: how the joint

* The sense of smelling resides in the olfactory nerves, which are distributed in the cells and curious convoluted bones of the nose. In some classes of animals, as the dog, hare, sheep, &c. there are found astonishing scrolls of bony texture, giving a great extent of surface, on which are spread out fibrillæ of nervous matter: thus bearing a ratio to the acuteness of the sense of smell.

Mr. C. Bell observes:—" It is with manifest design that this organ, which so particularly admonishes us of the effluvia diffused in the air we breathe, should have been placed in the entrance to the canal of the lungs; it is in some measure a safeguard to the lungs, as the sensibility of the tongue is a guard to the alimentary canal."

and adjusted operation of several tendons is concerned in every stroke, yet that five hundred such strokes are drawn in a minute. Not a letter can be turned without more than one, or two, or three tendinous retractions, definite, both as to the choice of the tendon, and as to the space through which the retraction moves; yet how currently does the work proceed! and when we look at it, how faithful have the muscles been to their duty, how true to the order which endeavour or habit hath inculcated! For let it be remembered, that whilst a man's handwriting is the same, an exactitude of order is preserved, whether he write well or ill. These two instances, of music and writing, show not only the quickness and precision of muscular action, but the docility.

II. Regarding the particular configuration of muscles, *sphincter* or circular muscles appear to me admirable pieces of mechanism.* It is the muscular power most happily applied; the same quality of the muscular substance, but under a new modification. The circular disposition of the fibres is strictly mechanical; but, though the most mechanical, is not the only thing in sphincters which deserves our notice. The regulated degree of contractile force with which they are endowed,

* Tab. XIV. Fig. 3. exhibits examples of *sphincter* muscles: *a, a,* the *orbicularis palpebrarum* encircling the eye-lid; it closes the eye, and compresses it with spasmodic force, when injured by particles of dust, &c. *b,* the *orbicularis oris,* surrounding the mouth; its chief use is to contract the lips.

sufficient for retention, yet vincible when requisite, together with their ordinary state of actual contraction, by means of which their dependence upon the will is not constant, but occasional, gives to them a constitution, of which the conveniency is inestimable. This their semi-voluntary character, is exactly such as suits with the wants and functions of the animal.*

III. We may also, upon the subject of muscles, observe, that many of our most important actions are achieved by the combined help of different muscles. Frequently, a diagonal motion is produced by the retraction of tendons pulling in the direction of the sides of the parallelogram. This is the case, as hath already been noticed, with some of the oblique nutations of the head. Sometimes the number of co-operating muscles is very great. Dr. Nieuentyt, in the Leipsic Transactions, reckons up a hundred muscles that are employed every time we breathe; yet we take in, or let out, our breath, without reflecting what a work is thereby performed; what an apparatus is laid

* Those muscles which are under the direct influence of the will are called *voluntary muscles.* Such are the muscles of loco-motion. But there are other muscles over which we have no control; these are *involuntary muscles:* the heart, arteries, and intestines are examples of this description; and it is remarkable that such muscles are not fatigued; though in continual action. The third or intermediate class of muscles, here termed *semi-voluntary*, are those whose action we can increase or suspend at pleasure, yet their regular actions are continued without our consciousness. The diaphragm and other muscles of breathing, and the muscles of winking, are of this class.

in, of instruments for the service, and how many such contribute their assistance to the effect! Breathing with ease, is a blessing of every moment; yet, of all others, it is that which we possess with the least consciousness. A man in an asthma is the only man who knows how to estimate it.

IV. Sir Everard Home has observed,* that the most important and the most delicate actions are performed in the body by the smallest muscles; and he mentions, as his examples, the muscles which have been discovered in the iris of the eye, and the drum of the ear. The tenuity of these muscles is astonishing. They are microscopic hairs; must be magnified to be visible; yet are they real effective muscles;† and not only such, but the grandest and most precious of our faculties, sight and hearing, depend upon their health and action.

V. The muscles act in the limbs with what is called a mechanical disadvantage. The muscle at the shoulder,‡ by which the arm is raised, is fixed nearly in the same manner as the load is fixed upon a steelyard, within a few decimals, we will say, of an inch, from the centre upon which the steelyard turns. In this situation, we find that

* Philosophical Transactions, Part I. 1800. p. 8.

† This statement will not so much excite our astonishment when we reflect, that every movement of the smallest insect is the effect of a muscular apparatus, the fibres of which must be proportionably minute.

‡ The *deltoid muscle*, see TAB. XIII. Fig. 1. *f*.

a very heavy draught is no more than sufficient to countervail the force of a small lead plummet, placed upon the long arm of the steelyard, at the distance of perhaps fifteen or twenty inches from the centre, and on the other side of it. And this is the disadvantage which is meant. And an absolute disadvantage, no doubt, it would be, if the object were to spare the force of muscular contraction. But observe how conducive is this constitution to animal conveniency. Mechanism has always in view one or other of these two purposes; either to move a great weight slowly, and through a small space, or to move a light weight rapidly, through a considerable sweep. For the former of these purposes, a different species of lever, and a different collocation of the muscles, might be better than the present; but for the second, the present structure is the true one. Now so it happens, that the second, and not the first, is that which the occasions of animal life principally call for. In what concerns the human body, it is of much more consequence to any man to be able to carry his hand to his head with due expedition, than it would be to have the power of raising from the ground a heavier load (of two or three more hundred weight, we will suppose,) than he can lift at present. This last is a faculty, which on some extraordinary occasions he may desire to possess; but the other is what he wants, and uses every hour or minute. In like manner, a husbandman, or a gardener, will do more execution, by being able to carry his scythe, his rake, or his flail, with a sufficient dispatch through a sufficient space, than if, with greater strength, his emotions were proportionably more confined and slow. It is the same with a mechanic in the use of his tools. It is the same also with other animals in the use of their limbs. In general, the vivacity of their motions would be ill exchanged for greater force under a clumsier structure.

We have offered our observations upon the structure of muscles in general; we have also noticed certain species of muscles; but there are also *single* muscles, which bear marks of mechanical contrivance, appropriate as well as particular. Out of many instances of this kind, we select the following.

I. Of muscular actions, even of those which are well understood, some of the most curious are incapable of popular explanation; at least, without the aid of plates and figures. This is in a great measure the case, with a very familiar, but, at the same time, a very complicated motion—that of the *lower jaw*; and with the muscular structure by which it is produced. One of the muscles concerned may, however, be described in such a manner, as to be, I think, sufficiently comprehended for our present purpose. The problem is to pull the lower jaw *down*. The obvious method should seem to be, to place a straight muscle, viz. to fix a string from the chin to the breast, the contraction of which would open the mouth, and produce the motion required at once. But it is evident that the form and liberty of the neck forbid a muscle being laid in such a position; and that, consistently with the preservation of this form, the motion, which we want, must be effectuated by some muscular mechanism disposed farther back in the jaw. The mechanism adopted is as follows: A certain muscle called the *digastric*, rises on the side of the face, considerably *above* the insertion of the lower jaw, and comes down, being converted in its progress into a round tendon. Now, it is manifest that the tendon, whilst it pursues a direction *descending* towards the jaw, must, by its contraction, pull the jaw up, instead of down. What then was to be done? This, we find, is done: The descending tendon, when it is got low enough, is passed through a loop, or ring, or pulley, in the os hyoides, and then made to ascend: and, having thus changed its line of direction, is inserted into the inner part of the chin: by which device, viz. the turn at the loop, the action of the muscle (which in all muscles is contraction) that before would have pulled the jaw up, now as necessarily draws it down. "The mouth," says Heister, "is opened by means of this trochlea in a most wonderful and elegant manner." *

* Tab. XV. Fig. 1 and 2. The *digastric muscle* has its origin,

TAB. XV.

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II. What contrivance can be more mechanical than the following, viz. a slit in one tendon to let another tendon pass through it? This structure is found in the tendons which move the toes and fingers.* The long tendon, as it is called, in the foot, which bends the first joint of the toe, passes *through* the short tendon which bends the second joint; which course allows to the sinew more liberty, and a more commodious action than it would otherwise have been capable of exerting. There is nothing, I believe, in a silk or cotton mill, in the belts, or straps, or ropes, by which motion is communicated from one part of the machine to another, that is more artificial, or more evidently so, than this *perforation.*

III. The next circumstance which I shall mention, under this head of muscular arrangement, is so decisive a mark of intention, that it always appeared to me to supersede, in some measure,

a, at the lower part of the temporal bone; it runs downwards and forwards, and forms a strong round tendon, *b*, which passes through a perforation in the stylo-hyoideus muscle, *f*; it is then fixed by a strong ligament, *c*, to the os hyoides, *d*; it again becomes fleshy, runs upwards, and is inserted into *e*, the chin. This description differs from the above, and it will be found by reference to dissections or the plate, that the os hyoides furnishes a *stay* or *brace* instead of a pulley, and that the *loop* or *ring* is in the stylo-hyoideus muscle.

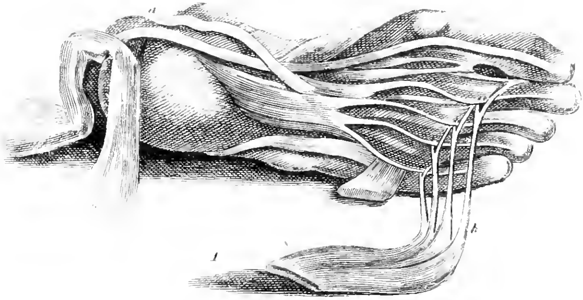
* Tab. XVI. Fig, 1. *a*, the tendon of the *long flexor of the toes*, which divides about the middle of the foot into four portions, which pass through the slits in, b, the *short flexor tendons*. Fig. 2. explains a similar contrivance belonging to each finger: *a*, a tendon of the *flexor sublimis*; *b*, a tendon of the *flexor profundus*, passing through it.

the necessity of seeking for any other observation upon the subject; and that circumstance is, the tendons, which pass from the leg to the foot, being bound down by a ligament at the ankle. The foot is placed at a considerable angle with the leg. It is manifest, therefore, that flexible strings, passing along the interior of the angle, if left to themselves, would, when stretched, start from it. The obvious preventive is to tie them down. And this is done in fact. Across the instep, or rather just above it, the anatomist finds a strong ligament *under* which the tendons pass to the foot.* The effect of the ligament as a bandage, can be made evident to the senses; for if it be cut, the tendons start up. The simplicity, yet the clearness of this contrivance, its exact resemblance to established resources of art, place it amongst the most indubitable manifestations of design with which we are acquainted.

There is also a further use to be made of the present example, and that is, as it precisely contradicts the opinion, that the parts of animals may have been all formed by what is called *appetency*, *i. e.* endeavour, perpetuated, and imperceptibly working its effect, through an incalculable series

* Tab. XVI. Fig. 3, *b*, *c*, tendons of the extensor muscles of the toes; *d*, the tendon of a flexor of the foot. These are bound down and retained *in situ* by *a*, the *annular* or *transverse ligament* of the instep, which consists of two distinct cross bands, going from the outer ankle to the inner ankle and neighbouring bones.

TAB. XVI



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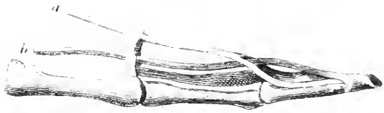

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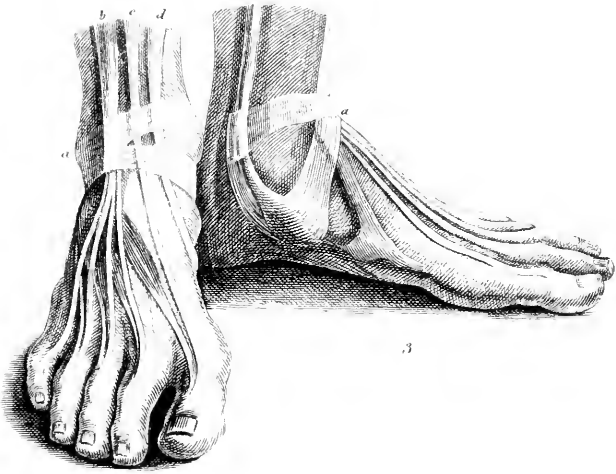

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of generations. We have here no endeavour, but the reverse of it; a constant renitency and reluctance. The endeavour is all the other way. The pressure of the ligament constrains the tendons; the tendons re-act upon the pressure of the ligament. It is impossible that the ligament should ever have been generated by the exercise of the tendon, or in the course of that exercise, forasmuch as the force of the tendon perpendicularly resists the fibre which confines it, and is constantly endeavouring, not to form, but to rupture and displace, the threads of which the ligament is composed.

Keill has reckoned up, in the human body, four hundred and forty-six muscles,* dissectible and describable; and hath assigned a use to every one of the number. This cannot be all imagination.

Bishop Wilkins hath observed from Galen, that there are, at least, ten several qualifications to be attended to in each particular muscle; viz. its proper figure; its just magnitude; its fulcrum; its point of action, supposing the figure to be fixed; its collocution, with respect to its two ends, the upper and the lower; the place; the position of the whole muscle; the introduction into it of nerves, arteries, veins. How are things, includ-

* In a former note it has been stated there are five hundred and twenty-seven muscles in the human frame independent of those which perform the internal vital motions; they are "dissectible and describable."

ing so many adjustments, to be made; or, when made, how are they to be put together, without intelligence?

I have sometimes wondered, why we are not struck with mechanism in animal bodies, as readily and as strongly as we are struck with it, at first sight, in a watch or a mill. One reason of the difference may be, that animal bodies are, in a great measure, made up of soft, flabby substances, such as muscles and membranes; whereas we have been accustomed to trace mechanism in sharp lines, in the configuration of hard materials, in the moulding, chiseling, and filing into shapes, of such articles as metals or wood. There is something therefore of habit in the case; but it is sufficiently evident, that there can be no proper reason for any distinction of the sort. Mechanism may be displayed in one kind of substance, as well as in the other.

Although the few instances we have selected, even as they stand in our description, are nothing short perhaps of logical proofs of design, yet it must not be forgotten, that, in every part of anatomy, description is a poor substitute for inspection. It is well said by an able anatomist,* and said in reference to the very part of the subject which we have been treating of:—"Imperfecta hæc musculorum descriptio, non minus arida est legentibus, quam inspectantibus fuerit jucunda

* Steno, in Blas. Anat. Animal. p. 2. c. 4.

eorundem præparatio. Elegantissima enim mechanices artificia, creberrime in illis obvia, verbis nonnisi obscure exprimuntur: carnium autem ductu, tendium colore, insertionum proportione, et trochlearium distributione, oculis exposita, omnem superant admirationem."*

CHAPTER X.

OF THE VESSELS OF ANIMAL BODIES.

The circulation of the *blood*, through the bodies of men and quadrupeds, and the apparatus by which it is carried on, compose a system, and testify a contrivance, perhaps the best understood of any part of the animal frame. The lymphatic system, or the nervous system, may be more subtile and intricate; nay, it is possible that in their

* For acquiring further knowledge of anatomy, we recommend the inspection of animals. It is a pursuit which would be neither attended with disgust or revolting to the finer feelings of our nature. And from the strong resemblance of quadrupeds to man, a very accurate notion may be obtained of our own structure. The bones, ligaments, muscles, tendons, membranes, vessels, &c. may be identified; they are formed of the same materials and of the same textures, and chiefly differ in their figure and proportions. For surgical anatomy, we are sensible that nothing but a patient and attentive examination of the human body will suffice; but for general anatomy, as it respects structure, we may observe the same display of animal mechanism in the dissection of quadrupeds.

structure they may be even more artificial than the sanguiferous; but we do not know so much about them.

The utility of the circulation of the blood I assume as an acknowledged point. One grand purpose is plainly answered by it; the distributing to every part, every extremity, every nook and corner of the body, the nourishment which is received into it by one aperture. What enters at the mouth finds its way to the fingers' ends. A more difficult mechanical problem could hardly, I think, be proposed, than to discover a method of constantly repairing the waste, and of supplying an accession of substance to every part of a complicated machine, at the same time.

This system presents itself under two views: first, the disposition of the blood-vessels, *i. e.* the laying of the pipes; and secondly, the construction of the engine at the centre, viz. the heart, for driving the blood through them.

I. The disposition of the blood-vessels, as far regards the supply of the body, is like that of the water-pipes in a city, viz. large and main trunks branching off by smaller pipes (and these again by still narrower tubes) in every direction, and towards every part in which the fluid, which they convey, can be wanted. So far the water-pipes, which serve a town, may represent the vessels which carry the blood from the heart. But there is another thing necessary to the blood, which is not wanted for the water; and that is, the carrying of it back again to its source. For this office, a reversed system of vessels is prepared, which, uniting at their extremities with the extremities of the first system, collects the divided and sub-divided streamlets, first, by capillary ramifications into longer branches; secondly, by these branches into trunks; and thus returns the blood (almost exactly inverting the order in which it went out) to the fountain whence its motion proceeded. All which is evident mechanism.*

The body, therefore, contains two systems of blood-vessels, arteries and veins. Between the constitution of the systems there are also two differences, suited to the functions which the systems have to execute. The blood, in going out, passing always from wider into narrower tubes; and, in coming back, from narrower into wider; it is evident, that the impulse and pressure upon the sides of the blood-vessel will be much greater in one case than the other. Accordingly, the arteries which carry out the blood, are formed of much tougher and stronger coats,† than the veins which

* From this description of the vessels it must not be inferred that the circulation is merely a mechanical effect, explicable by the principles of hydraulics: the *arteries* are living tubes, endowed with the power of muscular contraction, by which at each pulsation, the vital stream is propelled not only through the arteries themselves, but also through the veins again to the heart.

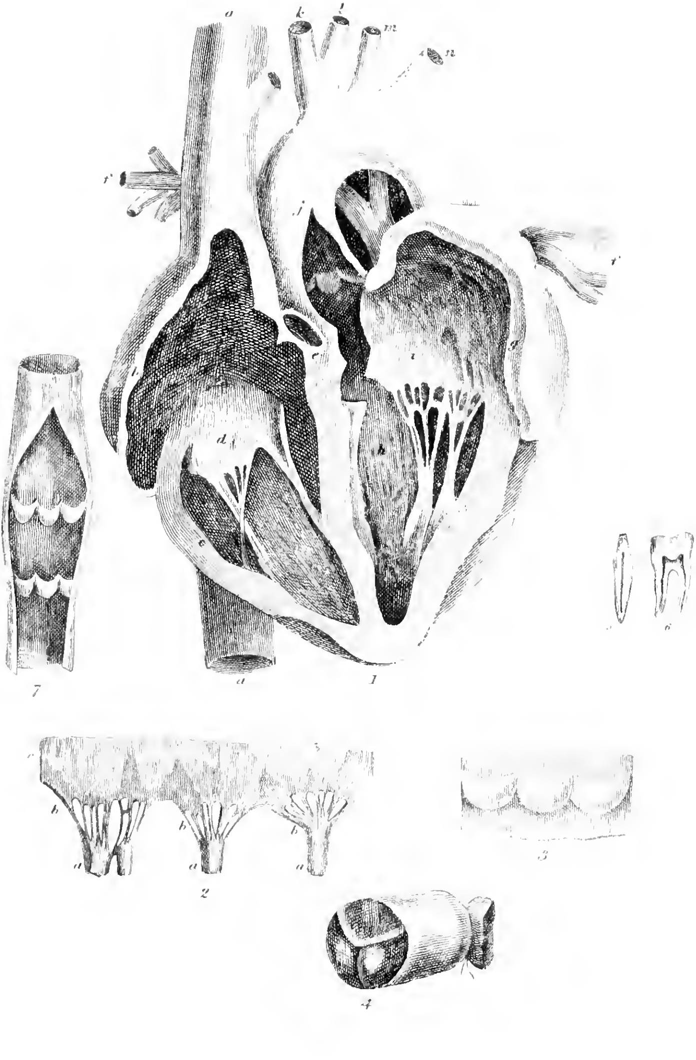
† The arteries are strong elastic pulsating canals, whose contractions assist in continuing the stream of blood from the heart. The veins do not pulsate, and have a more delicate structure.

bring it back. That is one difference: the other is still more artificial, or, if I may so speak, indicates, still more clearly, the care and anxiety of the artificer. Forasmuch as in the arteries, by reason of the great force with which the blood is urged along them, a wound or rupture would be more dangerous than in the veins, these vessels are defended from injury, not only by their texture, but by their situation; and by every advantage of situation which can be given to them. They are buried in sinuses, or they creep along grooves, made for them in the bones; for instance, the under edge of the ribs is sloped and furrowed solely for the passage of these vessels. Sometimes they proceed in channels, protected by stout parapets on each side; which last description is remarkable in the bones of the fingers, these being hollowed out, on the under side, like a scoop, and with such a concavity, that the finger may be cut across to the bone, without hurting the artery which runs along it. At other times, the arteries pass in canals wrought in the substance, and in the very middle of the substance of the bone; this takes place in the lower jaw; and is found where there would, otherwise, be danger of compression by sudden curvature. All this care is wonderful, yet not more than what the importance of the case required. To those who venture their lives in a ship, it has been often said, that there is only an inch board between them and death; but in the body itself especially in the arterial system, there is, in many parts, only a membrane, a skin, a thread. For which reason, this system lies deep under the integuments; whereas the veins, in which the mischief that ensues from injuring the coats is much less, lie in general above the arteries; come nearer to the surface; are more exposed.

It may be farther observed concerning the two systems taken together, that though the arterial, with its trunk and branches and small twigs, may be imagined to issue or proceed, in other words, to *grow* from the heart; like a plant from its root, or the fibres of a leaf from its foot-stalk, (which, however, were it so, would be only to resolve one mechanism into another,) yet the venal, the returning system, can never be formed in this manner. The arteries might go on shooting out from their extremities, *i. e.* lengthening and subdividing indefinitely; but an inverted system, continually uniting its streams, instead of dividing, and thus carrying back what the other system carried out, could not be referred to the same process.

II. The next thing to be considered is the engine which works this machinery, viz. the *heart*. For our purpose it is unnecessary to ascertain the principle upon which the heart acts. Whether it be irritation excited by the contact of the blood, by the influx of the nervous fluid, or whatever else be the cause of its motion, it is something which is capable of producing, in a living muscular fibre, reciprocal contraction and relaxation. This is the power we have to work with; and the inquiry is, how this power is applied in the instance before us. There is provided, in the central part of the body, a hollow muscle, invested with spiral fibres, running in both directions, the layers intersecting one another; in some animals, however, appearing to be semicircular rather than spiral. By the contraction of these fibres, the sides of the muscular cavities are necessarily squeezed together, so as to force out from them any fluid which they may at that time contain: by the relaxation of the same fibres, the cavities are in their turn dilated, and, of course, prepared to admit every fluid which may be poured into them. Into these cavities are inserted the great trunks, both of the arteries which carry out the blood, and of the veins which bring it back.* This is a general account of the apparatus: and the simplest idea of its action is, that, by each contraction, a portion of blood is forced by a syringe into the arteries; and, at each, dilatation, an equal portion is received from the

* Tab. XVII. Fig. 1. a section of the human heart; *a*, *a*, the *superior* and *inferior vena cava*, the veins which convey the blood to the *right auricle*, *b*, and thence into the corresponding *ventricle*, *c*; from this ventricle the blood is impelled through the *pulmonary artery*, *e*, into the lungs; and returning by the pulmonary veins, *f*, *f*, it is received into the *left auricle*, *g*: it flows next into the *left ventricle*, *h*; which by its contraction distributes the blood through the general arterial system;—*j*, the *aorta*, the great artery which transmits blood to the different parts of the body, from whence it is returned by veins to the *cavæ*.



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veins. This produces, at each pulse, a motion, and change in the mass of blood, to the amount of what the cavity contains, which, in a full-grown human heart, I understand, is about an ounce, or two table-spoons full. How quickly these changes succeed one another, and by this succession how sufficient they are to support a stream or circulation throughout the system, may be understood by the following computation, abridged from Keill's Anatomy, p. 177. edit. 3. "Each ventricle will at least contain one ounce of blood. The heart contracts four thousand times in one hour; from which it follows, that there pass through the heart, every hour, four thousand ounces, or three hundred and fifty pounds of blood. Now the whole mass of blood is said to be about twenty-five pounds; so that a quantity of blood, equal to the whole mass of blood, passes through the heart fourteen times in one hour; which is about once every four minutes." Consider what an affair this is, when we come to very large animals. The aorta of the whale is larger in the bore than the main pipe of the water-works at London-bridge; and the water roaring in its passage through that pipe is inferior in impetus and velocity, to the blood gushing from the whale's heart. Hear Dr. Hunter's account of the dissection of the whale:—The aorta measured a foot diameter. Ten or fifteen gallons of blood are thrown out of the heart at a stroke with an immense velocity, through a tube of a foot diameter. The whole idea fills the mind with wonder."*

The account which we have here stated, of the injection of blood into the arteries by the contraction, and of the corresponding reception of it from the veins by the dilatation, of the cavities of the heart, and of the circulation being thereby maintained through the blood-vessels of the body, is true, but imperfect. The heart performs this office, but it is in conjunction with another of equal curiosity and importance. It was necessary that the blood should be successively brought into contact, or contiguity, or proximity, with the *air*. I do not know that the chemical reason, upon which this necessity is founded, has been yet sufficiently explored. It seems to be made appear, that the atmosphere which we breathe is a mixture of two kinds of air; one pure and vital, the other, for the purposes of life, effete, foul, and noxious:† that when we have drawn in our breath, the blood in the lungs imbibes from the air, thus brought into contiguity with it, a portion of its

* Dr. Hunter's Account of the Dissection of a Whale. (Philosophical Transactions.)

† Atmospheric air consists of about twenty parts of oxygen gas, and eighty of azotic gas; it also contains a portion of other gases, vapour, &c. But it is the oxygen which supports combustion and respiration, being indispensably necessary for the life of animals and vegetables, hence called here "vital" air.

pure ingredient, and, at the same time, gives out the effete or corrupt air which it contained, and which is carried away, along with the halitus, every time we expire. At least, by comparing the air which is breathed from the lungs with the air which enters the lungs, it is found to have lost some of its pure part, and to have brought away with it an addition of its impure part. Whether these experiments satisfy the question, as to the need which the blood stands in of being visited by continual accesses of air, is not for us to inquire into, nor material to our argument: it is sufficient to know, that in the constitution of most animals, such a necessity exists, and that the air, by some means or other, *must* be introduced into a near communication with the blood.* The lungs of animals are constructed for this purpose. They consist of blood-vessels and air-vessels, lying close to each other; and wherever there is a branch of the trachea or windpipe, there is a branch accompanying it of the vein and artery, and the air-vessel is always in the middle between the blood-vessels. The internal surface of these vessels, upon which the application of air to the blood depends, would, if collected and expanded, be, in a man, equal to a superficies of fifteen feet square. Now, in order to give the blood in its course the

* Respiration is supposed also to be the principal source of animal heat. The heat of the blood increasing nearly a degree in passing through the lungs.

benefit of this organization, (and this is the part of the subject with which we are chiefly concerned,) the following operation takes place. As soon as the blood is received by the heart from the veins of the body, and *before* that is sent out again into its arteries, it is carried by the force of the contraction of the heart, and by means of a separate and supplementary artery, to the lungs, and made to enter the vessels of the lungs; from which, after it has undergone the action, whatever it be, of that viscus, it is brought back by a large vein once more to the heart, in order, when thus concocted and prepared, to be thence distributed anew into the system. This assigns to the heart a double office. The pulmonary circulation is a system within a system; and one action of the heart is the origin of both.*

For this complicated function, four cavities become necessary; and four are accordingly provided: two, called ventricles, which *send out* the blood, viz. one into the lungs, in the first instance; the other into the mass, after it has returned from the lungs: two others also, called auricles, which *receive* the blood from the veins; viz. one, as it

* The double office of the heart is very correctly described; one side being appropriated to the *pulmonary*, the other to the general system. On the *right side*, the blood arrives dark and unfit for the purposes of the circulation; but when it has reached the *left side*, from having traversed the lungs, in which it is exposed to the atmosphere, and has been purified, that is, the carbon of the blood has been thrown off, it then has acquired a florid colour, and is capable of supporting every function of life.

comes immediately from the body; the other, as the same blood comes a second time after its circulation through the lungs. So that there are two receiving cavities, and two forcing cavities. The structure of the heart has reference to the lungs; for without the lungs, one of each would have been sufficient. The translation of the blood in the heart itself is after this manner. The receiving cavities respectively communicate with the forcing cavities, and, by their contraction, unload the received blood into them. The forcing cavities, when it is their turn to contract, impel the same blood into the mouths of the arteries.

The account here given will not convey to a reader, ignorant of anatomy, any thing like an accurate notion of the form, action, or use of the parts, (nor can any short and popular account do this;) but it is abundantly sufficient to testify contrivance; and although imperfect, being true as far as it goes, may be relied upon for the only purpose for which we offer it, the purpose of this conclusion.

"The wisdom of the Creator," saith Hamburgher, "is in nothing seen more gloriously than in the heart." And how well doth it execute its office! An anatomist, who understood the structure of the heart, might say beforehand that it would play; but he would expect, I think, from the complexity of its mechanism, and the delicacy of many of its parts, that it should always be liable to derangement, or that it would soon work itself out. Yet shall this wonderful machine go, night and day, for eighty years together, at the rate of a hundred thousand strokes every twenty-four hours, having, at every stroke, a great resistance to overcome; and shall continue this action for this length of time, without disorder and without weariness!

But farther: from the account which has been given of the mechanism of the heart, it is evident that it must require the interposition of *valves;* that the success indeed of its action must depend upon these; for when any one of its cavities contracts, the necessary tendency of the force will be to drive the enclosed blood, not only into the mouth of the artery where it ought to go, but also back again into the mouth of the vein from which it flowed. In like manner, when by the relaxation of the fibres the same cavity is dilated, the blood would not only run into it from the vein, which was the course intended, but back from the artery, through which it ought to be moving forward. The way of preventing a reflux of the fluid, in both these cases, is to fix valves, which, like flood-gates, may open a way to the stream in one direction, and shut up the passage against it in another. The heart, constituted as it is, can no more work without valves than a pump can. When the piston descends in a pump, if it were not for the stoppage by the valve beneath, the motion would only thrust down the water which it had before drawn up. A similar consequence would frustrate the action of the heart. Valves, therefore, properly disposed, *i. e.* properly with respect to the course of the blood which it is necessary to promote, are essential to the contrivance. *And valves so disposed, are accordingly provided.** A valve is placed in the communication between each auricle and its ventricle, lest when the ventricle contracts, part of the blood should get back again into the auricle, instead of the whole entering, as it ought to do, the mouth of the artery. A valve is also fixed at the mouth of each of the great arteries which take the blood from the heart;† leaving the passage free, so long as the blood holds its proper course forward; closing it, whenever the blood, in consequence of the relaxation of the ventricle, would attempt to flow back. There is some variety in the construction of these valves, though all the valves of the body act nearly upon the same principle, and are destined to the same use. In general they consist of a thin membrane, lying close to the side of the

* Tab. XVII. Fig. 1. *d*, the *valves* of the right; *i*, the *valves* of the left ventricle. Fig. 2. the valves of the right side (*tricuspid valves*) separated from the heart; *a, a, a*, the *carneæ columnæ* or muscular fibres of the valves; *b, b, b*, the *chordæ tendineæ* or tendinous filaments which are attached to *c*, the valves.

† Fig. 3. exhibits the *artery* cut open with the form of the *semilunar valves*. Fig. 4. a portion of the artery filled, shewing how effectually these valves prevent the retrograde motion of the blood in the aorta and pulmonary artery.

vessel, and consequently allowing an open passage whilst the stream runs one way, but thrust out from the side by the fluid getting behind it, and opposite the passage of the blood, when it would flow the other way.* Where more than one membrane is employed, the different membranes only compose one valve. Their joint action fulfils the office of a valve: for instance; over the entrance of the right auricle of the heart into the right ventricle, three of these skins or membranes are fixed, of a triangular figure, the bases of the triangles fastened to the flesh; the sides and summits loose; but, though loose, connected by threads † of a determinate length, with certain small fleshy prominences adjoining.‡ The effect of this construction is, that, when the ventricle contracts, the blood endeavouring to escape in all directions, and amongst other directions pressing upwards, gets *between* these membranes and the sides of the heart; and thereby forces them up into such a position, as that, together, they constitute, when raised, a hollow cone, (the strings, before spoken of, hindering them from proceeding

* The veins and absorbent vessels present in their cavities folds of a parabolic form, called *valves*, like the semi-lunar valve; the one edge adheres to the sides of the vein, the other is loose, the first is farthest from the heart, the other nearer. The number of valves is greatest where the blood flows contrary to the force of its own weight. See Fig. 7.

† The tendinous filaments, Fig, 2. *b*, *b*, *b*.

‡ The muscular fibres of the valve, *a*, *a*, *a*.

or separating farther;) which cone, entirely occupying the passage, prevents the return of the blood into the auricle. A shorter account of the matter may be this: So long as the blood proceeds in its proper course, the membranes which compose the valve are pressed close to the side of the vessel, and occasion no impediment to the circulation: when the blood would regurgitate, they are raised from the side of the vessel, and, meeting in the middle of its cavity, shut up the channel. Can any one doubt of contrivance here; or is it possible to shut our eyes against the proof of it?

This valve, also, is not more curious in its structure, than it is important in its office. Upon the play of the valve, even upon the proportioned length of the strings or fibres which check the ascent of the membranes, depends, as it should seem, nothing less than the life itself of the animal. We may here likewise repeat, what we before observed concerning some of the ligaments of the body, that they could not be formed by any action of the parts themselves. There are cases in which, although good uses appear to arise from the shape or configuration of a part, yet that shape or configuration itself may seem to be produced by the action of the part, or by the action or pressure of adjoining parts. Thus the bend, and the internal smooth concavity of the ribs, may be attributed to the equal pressure of the soft viscera; the particular shape of some bones and joints, to the traction of the annexed muscles, or to the position of contiguous muscles. But valves could not be so formed. Action and pressure are all against them. The blood, in its proper course, has no tendency to produce such things; and, in its improper or reflected current, has a tendency to prevent their production. Whilst we see, therefore, the use and necessity of this machinery, we can look to no other account of its origin or formation than the intending mind of a Creator. Nor can we without admiration reflect, that such thin membranes, such weak and tender instruments, as these valves are, should be able to hold out for seventy or eighty years.

Here also we cannot consider but with gratitude, how happy it is that our vital motions * are *involuntary*. We should have enough to do, if we had to keep our hearts beating, and our stomachs at work. Did these things depend, we will not say upon our effort, but upon our bidding, our

* "Vital motions." Much has been written on this subject by physiologists, shewing that, besides the heart and stomach, there are many other parts of the body which exhibit, either continually or at periods, the phenomenon of *vital action*—as, for instance, the liver, by virtue of a power which is peculiar to it, continually forms bile—the same thing takes place in the kidneys with regard to urine.—The same power, of the mechanism of which we are ignorant, carries on the process of secretion in glands and exhalation from surfaces—by it the arteries pulsate, the intestines press forward their contents. Vital or organic action, therefore, performs a very considerable part, both in the life of man and animals.

care, or our attention, they would leave us leisure for nothing else. We must have been continually upon the watch, and continually in fear; nor would this constitution have allowed of sleep.

It might perhaps be expected, that an organ so precious, of such central and primary importance as the heart is, should be defended by *a case*. The fact is, that a membranous purse or bag, made of strong, tough materials, is provided for it; holding the heart within its cavity;* sitting loosely and easily about it; guarding its substance, without confining its motion; and containing likewise a spoonful or two of water, just sufficient to keep the surface of the heart in a state of suppleness and moisture. How should such a loose covering be generated by the action of the heart? Does not the enclosing of it in a sack, answering no other purpose but that enclosure, show the care that has been taken of its preservation?

One use of the circulation of the blood probably (amongst other uses) is, to distribute nourishment to the different parts of the body. How minute and multiplied the ramifications of the blood-vessels, for that purpose, are; and how thickly spread, over at least the superficies of the body, is proved by the single observation, that we cannot prick the point of a pin into the flesh, without drawing blood, *i. e.* without finding a blood-vessel. Nor,

* This cavity is the *pericardium*; it secretes, *i. e.* produces that fluid which lubricates the surface of the heart, and diminishes the effects of friction.

internally, is their diffusion less universal. Blood-vessels run along the surface of membranes, pervade the substance of muscles, penetrate the bones. Even into every tooth, we trace, through a small hole in the root, an artery to feed the bone, as well as a vein to bring back the spare blood from it; both which, with the addition of an accompanying nerve, form a thread only a little thicker than a horse-hair.*

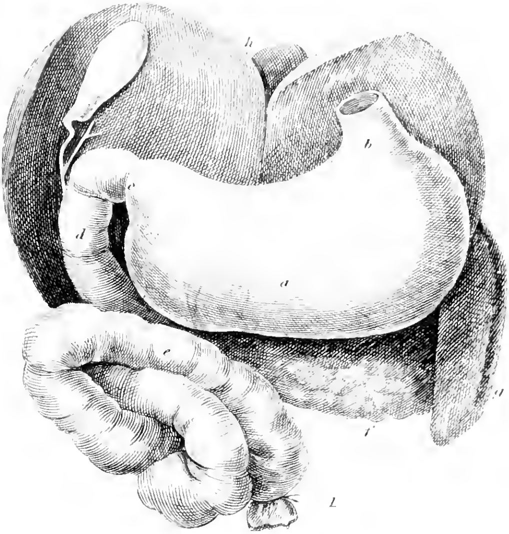
Wherefore, when the nourishment taken in at the mouth has once reached, and mixed itself with the blood, every part of the body is in the way of being supplied with it. And this introduces another grand topic, namely, the manner in which the aliment gets into the *blood;* which is a subject distinct from the preceding, and brings us to the consideration of another entire system of vessels.

II. For this necessary part of the animal economy, an apparatus is provided, in a great measure capable of being what anatomists call demonstrated, that is, shown in the dead body;—and a line or course of conveyance, which we can pursue by our examinations.

First, The food descends by a wide passage into the intestines, undergoing two great preparations on its way; one, in the mouth by mastication and

* Tab. XVI. Fig. 5. and 6. a section of a cutting and grinding tooth, shewing the apertures at the root and the cavities for the vessels and nerves, which supply the bony part of the teeth, the enamel not being an organized substance.

TAB.



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moisture—(can it be doubted with what design the teeth were placed in the road to the stomach, or that there was choice in fixing them in this situation?) the other, by digestion in the stomach itself. Of this last surprising dissolution I say nothing; because it is chemistry, and I am endeavouring to display mechanism. The figure and position of the stomach (I speak all along with a reference to the human organ) are calculated for detaining the food long enough for the action of its digestive juice. It has the shape of the pouch of a bagpipe; lies across the body; and the pylorus, or passage by which the food leaves it, is somewhat higher in the body than the cardia, or orifice by which it enters;* so that it is by the contraction of the muscular coat of the stomach, that the contents, after having undergone the application of the gastric menstruum, are gradually pressed out. In dogs and cats, this action of the coats of the stomach has been displayed to the eye.

* Tab. XVIII. Fig. 1. *a*, the *stomach*; *b*, the *cardia*; *c*, the *pylorus*. It is a capacious receptacle of an extensible and contractile nature, destined to contain alimentary substances in order to their formation into chyle. The digestive organs therefore act upon the aliments, changing and decomposing them, and separate from them the gross and inert portion, which is thrown off; while the nutritive juice, the useful part called *chyle* is preserved and penetrates into the most remote recesses of the body, repairing the incessant loss occasioned by perspiration, urine, respiration, &c. amounting to several pounds in twenty-four hours. This would reduce our strength, and we should soon perish, were we not to repair the loss and our strength together by a new supply of nourishment and drink.

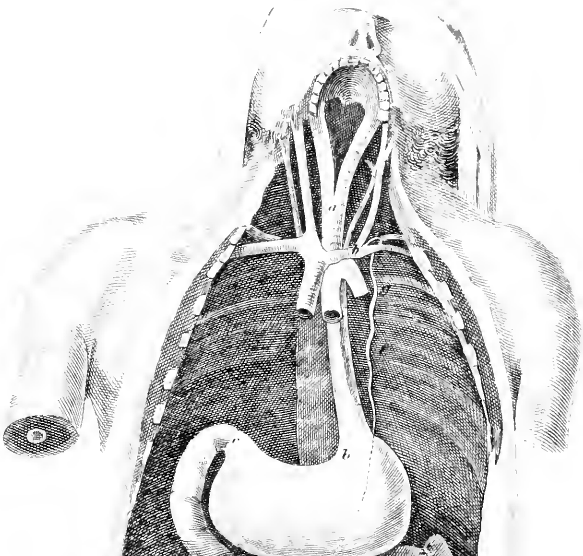
It is a slow and gentle undulation, propagated from one orifice of the stomach to the other. For the same reason that I omitted, for the present, offering any observation upon the digestive fluid, I shall say nothing concerning the bile or the pancreatic juice,* farther than to observe upon the mechanism, viz. that from the glands in which these secretions are elaborated, pipes are laid into the first of the intestines, through which pipes the product of each gland flows into that bowel,† and is there mixed with the aliment, as soon almost as it passes the stomach; adding also as a remark, how grievously the same bile offends the stomach itself, yet cherishes the vessel that lies next to it.‡

Secondly, We have now the aliment in the intestines converted into pulp; and, though lately consisting of ten different viands, reduced to nearly a uniform substance, and to a state fitted for yielding its essence, which is called chyle, but which is milk, or more nearly resembling milk than any other liquor with which it can be com-

* The pancreas secretes a fluid resembling saliva, which, mixing with the contents of the intestines, assists in dissolving the alimentary matter, and thus performs the office of a salivary gland.

† Fig. 2. *e*, the opening common to *the biliary and pancreatic ducts*.

‡ The *bile* is important in the animal economy. The primary uses of this fluid are, 1. To separate the chyle. 2. By its acrid quality to excite the peristaltic motion of the intestines. 3. To prevent the abundance of mucus and acidity in the intestinal canal: hence jaundice, constipation, and various other diseases, are common from deficient or inert bile.



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pared. For the straining off this fluid from the digested aliment in the course of its long progress through the body, myriads of capillary tubes, *i. e.* pipes as small as hairs, open their orifices into the cavity of every part of the intestines. These tubes, which are so fine and slender as not to be visible unless when distended with chyle, soon unite into larger branches. The pipes, formed by this union, terminate in glands, from which other pipes of a still larger diameter arising, carry the chyle from all parts, into a common reservoir or *receptacle*. This receptacle is a bag of size enough to hold about a table-spoon full; and from this vessel a duct or main pipe proceeds, climbing up the back part of the chest, and afterwards creeping along the gullet till it reach the neck. Here it meets the river: here it discharges itself into a large vein, which soon conveys the chyle, now flowing along with the old blood, to the heart. This whole rout can be exhibited to the eye; nothing is left to be supplied by imagination or conjecture.* Now, beside the subserviency of

* Tab. XIX. represents the course of the food, from its entrance at the mouth to its assimilation with the blood; *a*, the *œsophagus*, extending from the *pharynx* to *b*, the *stomach;* where the alimentary matter, having undergone the digestive process, is converted into *chyme*, a soft homogenious substance, and escapes at *c*, the *pylorus*, into *d*, *d*, the *intestines*. In this plate a large portion of the latter is spread out to shew a part of the absorbent system called *lacteals:* these collect and imbibe the *chyle*, or milky juice from the *chyme*, and transmit it through *e*, *e*, the *mesenteric glands*, into one general receptacle. *f*, (*receptaculum*

this structure, collectively considered, to a manifest and necessary purpose, we may remark two or three separate particulars in it, which show, not only the contrivance, but the perfection of it. We may remark, first, the length of the intestines, which in the human subject, is six times that of the body. Simply for a passage, these voluminous bowels, this prolixity of gut, seems in no wise necessary; but, in order to allow time and space for the successive extraction of the chyle from the digested aliment, namely, that the chyle which escapes the lacteals of one part of the guts, may be taken up by those of some other part, the length of the canal is of evident use and conduciveness. Secondly, we must also remark their peristaltic motion; which is made of contractions, following one another like waves upon the surface of a fluid, and not unlike what we observe in the body of an earth-worm crawling along the ground; and which is effected by the joint action of longitudinal and of spiral, or rather perhaps of a great number of separate semicircular fibres.* This curious action pushes forward the grosser

chyli,) from which *g*, the *thoracic duct*, ascends in a more or less tortuous direction to the lower vertebræ of the neck, and after forming an arch, it descends and enters *h*, the left *subclavian vein*, at the point where that vein is united with the *internal jugular*. The absorbents of the right side generally form a trunk, which enters the *right subclavian vein*.

* These are *muscular fibres;* the longitudinal shorten the canal, the circular fibres contract it; and their conjoined action produces the *peristaltic motion*.

part of the aliment, at the same time that the more subtile parts, which we call chyle, are, by a series of gentle compressions, squeezed into the narrow orifices of the lacteal vessels. Thirdly, it was necessary that these tubes, which we denominate lacteals, or their mouths at least, should be as narrow as possible, in order to deny admission into the blood to any particle which is of size enough to make a lodgment afterwards in the small arteries, and thereby to obstruct the circulation: and it was also necessary that this extreme tenuity should be compensated by multitude; for, a large quantity of chyle (in ordinary constitutions, not less, it has been computed, than two or three quarts in a day) is, by some means or other, to be passed through them. Accordingly, we find the number of the lacteals exceeding all powers of computation; and their pipes so fine and slender, as not to be visible, unless filled, to the naked eye;* and their orifices, which open into the intestines, so small, as not to be discernible even by the best microscope. Fourthly, the main pipe, which carries the chyle from the reservoir to the blood, viz. the thoracic duct, being fixed in an almost upright position, and wanting

* By feeding an animal with milk, and killing it in two hours afterwards, then immediately opening the abdomen, the lacteals may be distinctly observed. Or if a ligature is tied round the root of the mesentery, and the intestines and mesentery immersed into spirits of wine, the chyle becomes white and opaque, and the vessels may be easily traced.

that advantage of propulsion which the arteries possess, is furnished with a succession of valves* to check the ascending fluid, when once it has passed them, from falling back. These valves look upward, so as to leave the ascent free, but to prevent the return of the chyle, if, for want of sufficient force to push it on, its weight should at any time cause it to descend. Fifthly, the chyle enters the blood in an odd place, but perhaps the most commodious place possible, viz. at a large vein near the neck, so situated with respect to the circulation, as speedily to bring the mixture to the heart. And this seems to be a circumstance of great moment; for had the chyle entered the blood at an artery, or at a distant vein, the fluid, composed of the old and new materials, must have performed a considerable part of the circulation, before it received that churning in the lungs, which is probably necessary for the intimate and perfect union of the old blood with the recent chyle. Who could have dreamt of a communication between the cavity of the intestines and the left great vein near the *neck?* Who could have

* The lacteals and absorbents have numerous *valves*, which are constantly disposed in pairs; these are of a semicircular form, connected by the semicircular edge to the inner surface of the vessels, and having the straight edge corresponding with the opposite valve loose in the cavity. The situation of the valves is indicated externally by a knotted appearance, which the absorbents in general assume. A contractile power is also assigned to them, by which these vessels urge forward their contents.

suspected that this communication should be the medium through which all nourishment* is derived to the body? or this the place, where, by a side-inlet, the important junction is formed between the blood and the material which feeds it?

We postponed the consideration of *digestion*, lest it should interrupt us in tracing the course of the food to the blood; but, in treating of the alimentary system, so principal a part of the process cannot be omitted.

Of the gastric juice, the immediate agent by which that change which food undergoes in our stomachs is effected, we shall take our account from the numerous, careful, and varied experiments of the Abbe Spallanzani.

1. It is not a simple diluent, but a real solvent. A quarter of an ounce of beef had scarcely touched the stomach of a crow, when the solution began.

2. It has not the nature of saliva; it has not the nature of bile; but is distinct from both. By experiments out of the body it appears, that neither of these secretions acts upon the alimentary substances, in the same manner as the gastric juice acts.

3. Digestion is not *putrefaction*; for, the digesting fluid resists putrefaction most pertina-

* "All nourishment." At present it is maintained by Magendie and other able physiologists, that the veins also have the power of absorbing; and that they absorb all fluids passing through the intestines except the chyle.

ciously; nay, not only checks its farther progress, but restores putrid substances.

4. It is not a *fermentative* process; for the solution begins at the surface, and proceeds towards the centre, contrary to the order in which fermentation acts and spreads.

5. It is not the *digestion of heat*, for, the cold maw of a cod or sturgeon will dissolve the shells of crabs or lobsters, harder than the sides of the stomach which contains them.*

In a word, animal digestion carries about it the marks of being a power and a process completely *sui generis;* distinct from every other; at least from every chemical process with which we are acquainted.† And the most wonderful thing about it is its appropriation; its subserviency to the par-

* Fishes are of all animals the most voracious; their digestive powers are quick: whatever any of them are able to swallow possessed of life, or indeed dead animal substances, seems to be desirable food. They often meet each other in fierce opposition, when the fish with the largest swallow comes off with the victory. We have seen a pike, with one of its own species in its stomach half its own size.

† The *gastric juice* is a secretion principally derived from the inner membrane of the stomach, and digestion, or the solution of the food, is effected by it: although it is never found pure, but mixed with saliva, the mucus of the mouth, pharynx, and æsophagus. In the various orders of animated beings it differs, being adapted to the food on which they are accustomed to subsist. The food, when properly masticated, is dissolved by the gastric fluid, and converted into *chyme;* so that most kinds of the ingesta lose their specific qualities; and the chemical changes to which they would otherwise be liable, as putridity, rancidity, and fermentation, are thus prevented, when the stomach is in a healthy state.

ticular economy of each animal. The gastric juice of an owl, falcon, or kite, will not touch grain; no, not even to finish the macerated and half-digested pulse which is left in the crops of the sparrows that the bird devours. In poultry, the trituration of the gizzard, and the gastric juice, conspire in the work of digestion. The gastric juice will not dissolve the grain whilst it is whole. Entire grains of barley, enclosed in tubes or spherules, are not affected by it. But if the same grain be by any means broken or ground, the gastric juice immediately lays hold of it. Here then is wanted, and here we find, a combination of mechanism and chemistry. For the preparatory grinding, the gizzard lends its mill. And, as all mill-work should be strong, its structure is so, beyond that of any other muscle belonging to the animal. The internal coat also, or lining of the gizzard, is, for the same purpose, hard and cartilaginous. But, forasmuch as this is not the sort of animal substance suited for the reception of glands, or for secretion, the gastric juice, in this family, is not supplied, as in membraneous stomachs, by the stomach itself, but by the gullet, in which the feeding glands are placed, and from which it trickles down into the stomach.

In sheep, the gastric fluid has no effect in digesting plants, *unless they have been previously masticated*. It only produces a slight maceration; nearly such as common water would produce, in a degree of heat somewhat exceeding the medium temperature of the atmosphere. But provided that the plant has been reduced to pieces by chewing, the gastric juice then proceeds with it, first by softening its substance; next, by destroying its natural consistency; and, lastly, by dissolving it so completely, as not even to spare the toughest and most stringy parts, such as the nerves of the leaves.

So far our accurate and indefatigable Abbe.—Dr. Stevens of Edinburgh, in 1777, found, by experiments tried with perforated balls, that the gastric juice of the sheep and the ox speedily dissolved vegetables, but made no impression upon beef, mutton, and other animal bodies. Dr. Hunter discovered a property of this fluid, of a most curious kind; viz. that in the stomachs of animals which feed upon flesh, irresistibly as this fluid acts upon animal substances, it is only upon the *dead* substance that it operates at all. The *living* fibre suffers no injury from lying in contact with it. Worms and insects* are found alive in the stomachs of such animals. The coats of the human stomach, in a healthy state, are insensible to its presence: yet, in cases of sudden death, (wherein the gastric juice, not having been weakened by disease, retains its activity,) it has been known to eat a hole through the bowel which

* Worms and insects are found in the stomach of herbivorous animals only.

contains it.*† How nice is this discrimination of action, yet how necessary?

But to return to our hydraulics.

III. The gall-bladder is a very remarkable contrivance. It is the reservoir of a canal. It does not form the channel itself, *i. e.* the direct communication between the liver and the intestine, which is by another passage, viz. the ductus hepaticus, continued under the name of the ductus communis; but it lies adjacent to this channel, joining it by a duct of its own, the ductus cysticus; by which structure it is enabled, as occasion may require, to add its contents to, and increase the flow of bile into the duodenum.‡ And the posi-

* Philosophical Transactions, vol. lxii. p. 447.

† This opinion has been taken up on the authority of Mr. Hunter, and we are acquainted with several other cases on record of this sort of occurrence; but we receive them with much doubt. We have been in the habit of examining a great number of animals at different periods after death, and most of them carnivorous, whose gastric secretion is more active than that of the human stomach in dissolving animal matter; yet in these we never could find any erosion of the coats of the stomach, which must have been the case if it was possible for the gastric juice to have such effects. We consider the stomach, therefore, to be equally insensible to its presence in life or in death.

‡ Tab. XVIII. Fig. 1. In this plate, *h*, the *liver*, is turned up, in order to shew *i*, the *gall-bladder*, which is attached to its concave surface; *a*, the *stomach*; *d*, the *duodenum*, or first portion of intestine; *e*, the *intestines*; *f*, the *pancreas*; and *g*, the *spleen*. Fig. 2. explains the several ducts and their communication with the *duodenum*; *a*, the *gall-bladder*; *b*, the *ductus cysticus*; which, uniting with *c*, the *ductus hepaticus*, forms *d*, the *ductus communis*, terminating at *e*, the point where the bile is poured into the duodenum.

tion of the gall-bladder is such as to apply this structure to the best advantage. In its natural situation, it touches the exterior surface of the stomach, and consequently is compressed by the distension of that vessel: the effect of which compression is, to force out from the bag, and send into the duodenum, an extraordinary quantity of bile, to meet the extraordinary demand which the repletion of the stomach by food is about to occasion. Cheselden describes the gall-bladder as seated against the duodenum, and thereby liable to have its fluid pressed out, by the passage of the aliment through that cavity; which likewise will have the effect of causing it to be received into the intestine, at a right time, and in a due proportion.

There may be other purposes answered by this contrivance; and it is probable that there are. The contents of the gall-bladder are not exactly of the same kind as what passes from the liver through the direct passage. It is possible that the gall may be changed, and for some purposes meliorated, by keeping.*

The entrance of the gall-duct into the duodenum, furnishes another observation. Whenever either smaller tubes are inserted into larger tubes, or tubes into vessels and cavities, such receiving

* The bile is said to become more viscid, acrid, and bitter, from the thinner parts being absorbed during its retention in the gall-bladder.

tubes, vessels, or cavities, being subject to muscular constriction, we always find a contrivance to prevent *regurgitation*. In some cases, valves are used; in other cases, amongst which is that now before us, a different expedient is resorted to; which may be thus described. The gall-duct enters the duodenum obliquely: after it has pierced the first coat, it runs near two fingers' breadth *between* the coats, before it opens into the cavity of the intestine.* The same contrivance is used in another part, where there is exactly the same occasion for it, viz. in the insertion of the ureters in the bladder. These enter the bladder near its neck, running obliquely for the space of an inch between its coats. It is, in both cases, sufficiently evident, that this structure has a necessary mechanical tendency to resist regurgitation; for, whatever force acts in such a direction as to urge the fluid back into the orifices of the tubes, must, at the same time, stretch the coats of the vessels, and thereby compress that part of the tube which is included between them.

IV. Amongst the *vessels* of the human body, the pipe which conveys the saliva from the place

* The mode in which this duct perforates the intestines is shewn in Tab. XVIII. Fig. 2. *d*, the *ductus communis* at the point of its entrance, which, after passing between the muscular and inner coat of the duodenum opens into it at *e*. This oblique passage of the common duct through the coats of the duodenum, has the effect of a valve preventing the reflux of bile, and even of air from the intestine.

where it is made, to the place where it is wanted, deserves to be reckoned amongst the most intelligible pieces of mechanism with which we are acquainted. The saliva, we all know, is used in the mouth: but much of it is produced on the outside of the cheek, by the parotid gland, which lies between the ear and the angle of the lower jaw. In order to carry the secretion to its destination, there is laid from the gland, on the outside, a pipe about the thickness of a wheat straw, and about three fingers' breadth in length; which, after riding over the masseter muscle, bores for itself a hole through the very middle of the cheek; enters by that hole, which is a complete perforation of the buccinator muscle, into the mouth; and there discharges its fluid very copiously.*

V. Another exquisite structure, differing indeed from the four preceding instances in that it does not relate to the conveyance of fluids, but still belonging, like these, to the class of pipes, or conduits of the body, is seen in the *larynx*. We all know that there go down the throat two pipes,

* Tab. XX. Fig. 1. a dissection to exhibit the *parotid gland*. Fig. 2. explains the former; *a*, *a*, the integuments turned back; *b*, the *parotid gland*; *c*, its *pipe* or *duct* passing over the *masseter*, then perforating *d*, the *buccinator muscle*, and opening into the mouth opposite the second molar tooth. The flow of saliva into the mouth is incessant: and it is one of the most useful digestive fluids. It is favourable to the maceration and division of the food, it assists it in deglutition and transformation into chyme; it also renders more easy the motions of the tongue in speech and in singing.

TAB. XX

1

2

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one leading to the stomach, the other to the lungs; the one being the passage for the food, the other for the breath and voice: we know also that both these passages open into the bottom of the mouth; the gullet, necessarily, for the conveyance of food; and the wind-pipe, for speech and the modulation of sound, not much less so; therefore the difficulty was, the passages being so contiguous, to prevent the food, especially the liquids which we swallow into the stomach, from entering the wind-pipe, *i. e.* the road to the lungs; the consequence of which error, when it does happen, is perceived by the convulsive throes that are instantly produced. This business, which is very nice, is managed in this manner. The gullet (the passage for food) opens into the mouth like the cone or upper part of a funnel, the capacity of which forms indeed the bottom of the mouth. Into the side of this funnel, at the part which lies the lowest, enters the wind-pipe, by a chink or slit,* with a lid or

* "Chink or slit," called the glottis. This is the opening of the larynx, formed by the *arytenoid* cartilages, shewn in Tab. XXI. Fig. 1 and 2. *g*, *g*. These cartilages constitute the most important part of the larynx, being connected with ligaments called the vocal chords, upon the state of which the human voice more immediately depends. The edges of these cartilages vibrate in the production of the voice, on the same principle as that of the reed in a wind instrument of music. The arytenoid cartilages therefore might be called the human reed, the trachea the tube; and the sounds will be dull or sharp according as the cartilages are more or less pressed together, and their intensity more or less according to the force with which the air is expelled from the lungs.

We assert that there never have been employed in musical in-flap,* like a little tongue, accurately fitted to the orifice. The solids or liquids which we swallow, pass over this lid or flap, as they descend by the funnel into the gullet. Both the weight of the food, and the action of the muscles concerned in swallowing, contribute to keep the lid close down upon the aperture, whilst any thing is passing; whereas, by means of its natural cartilaginous spring, it raises itself a little as soon as the food is passed, thereby allowing a free inlet and outlet for the respiration of air by the lungs. Such is its structure: And we may here remark the almost complete success of the expedient, viz. how seldom it fails of its purpose, compared with the number of instances in which it fulfils it. Reflect how frequently we swallow, how constantly we breathe. In a city feast, for example, what deglutition, what anhelation! yet does this little cartilage, the epiglottis, so effectually interpose its office, so securely guard the entrance of the wind-pipe, that whilst morsel after morsel, draught after draught, are coursing one another over it, an accident of a crumb or a drop slipping into this passage, (which neverthe-

struments any reeds whose moveable plates could vary every instant in thickness and elasticity, so as to produce such various tones and inflections, as those of the human voice.

* "Lid or flap," or *epiglottis.* Fig. 1 and 2. *b*, *b*, is another cartilage or valve for protecting the opening of the glottis. In Fig. 1. it is pressed down with a probe to shew its office when we are in the act of deglutition, at other times its elasticity keeps it raised, as we see in Fig. 2.

less must be opened for the breath every second of time,) excites in the whole company, not only alarm by its danger, but surprise by its novelty. Not two guests are choked in a century.

There is no room for pretending that the action of the parts may have gradually formed the epiglottis: I do not mean in the same individual, but in a succession of generations. Not only the action of the parts has no such tendency, but the animal could not live, nor consequently the parts act, either without it, or with it in a half-formed state. The species was not to wait for the gradual formation or expansion of a part which was, from the first, necessary to the life of the individual.

Not only is the larynx * curious, but the whole wind-pipe possesses a structure adapted to its peculiar office. It is made up (as any one may perceive by putting his fingers to his throat) of stout

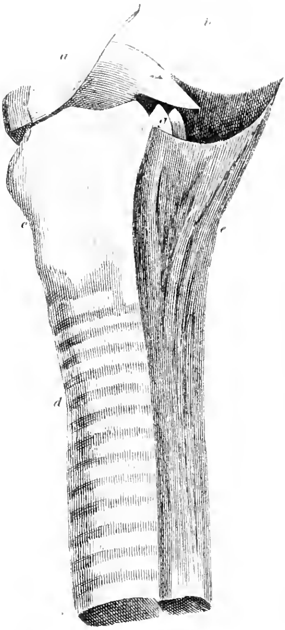
* Fig. 2. exhibits the *larynx* and *trachea*: the larynx is formed of five cartilages, viz. *b*, the *epiglottis*; *g*, the two *arytenoid cartilages*; *e*, the *thyroid cartilage*, exceedingly strong, for the protection of the upper part of the air tube; *h*, the *cricoid* cartilage; *d*, the *cartilaginous ringlets* of the *trachea or wind-pipe*, varying in number from sixteen to twenty, each forming nearly two-thirds of a circle, and completed by, *f*, a soft *membrane*, which, from its apposition to the œsophagus, accomodates itself to the substances passing into the stomach. The trachea finally divides into two great branches called *bronchi*, which are subdivided into very minute branches through the substance of the lungs. In birds the trachea is composed of cartilages which form complete rings, and these overlap each other at their edges in such a manner, that the diameter of the tube is not affected by any bending or twisting of the neck.

cartilaginous ringlets, placed at small and equal distances from one another. Now this is not the case with any other of the numerous conduits of the body. The use of these cartilages is to keep the passage for the air *constantly* open; which they do mechanically. A pipe with soft membranous coats, liable to collapse and close when empty, would not have answered here; although this be the general vascular structure, and a structure which serves very well for those tubes which are kept in a state of perpetual distension by the fluid they enclose, or which afford a passage to solid and protruding substances.

Nevertheless (which is another particularity well worthy of notice) these rings are not complete, that is, are not cartilaginous and stiff all round; but their hinder part, which is contiguous to the gullet, is membranous and soft, easily yielding to the distensions of that organ occasioned by the descent of solid food. The same rings are also bevelled off at the upper and lower edges, the better to close upon one another, when the trachea is compressed or shortened.

The constitution of the trachea may suggest likewise another reflection. The membrane which lines its inside is, perhaps, the most sensible irritable membrane of the body. It rejects the touch of a crumb of bread, or a drop of water, with a spasm which convulses the whole frame; yet, left to itself, and its proper office, the intromission of

TAB. XI.



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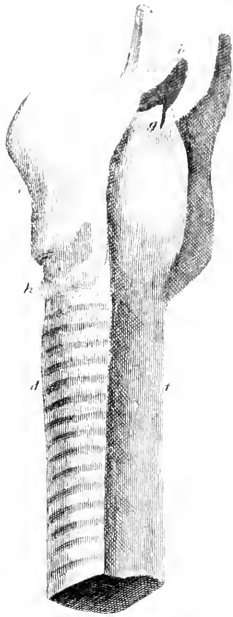

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3

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air alone, nothing can be so quiet. It does not even make itself felt; a man does not know that he has a trachea. This capacity of perceiving with such acuteness this impatience of offence, yet perfect rest and ease when let alone, are properties, one would have thought, not likely to reside in the same subject. It is to the junction, however, of these almost inconsistent qualities, in this, as well as in some other delicate parts of the body, that we owe our safety and our comfort;—our safety to their sensibility, our comfort to their repose.

The larynx, or rather the whole wind-pipe taken together, (for the larynx is only the upper part of the wind-pipe,) besides its other uses, is also a musical instrument, that is to say, it is *mechanism* expressly adapted to the modulation of sound; for it has been found upon trial, that, by relaxing or tightening the tendinous bands at the extremity of the wind-pipe, and blowing in at the other end, all the cries and notes might be produced of which the living animal was capable. It can be sounded, just as a pipe or flute is sounded.

Birds, says Bonnet, have at the lower end of the wind-pipe,* a conformation like the reed of a

* Tab. XXI. Fig. 3. This is called the *inferior larynx*, where the vocal organ is formed by a compression of the trachea, for it is here contracted into a narrow chink, and divided into two openings by a slender bone, or tense membrane, which, in producing sounds, resembles the mechanism of a musical instrument. In the plate this part of the larynx is a little turned up to shew the *tendinous*

hautboy, for the modulation of their notes. A tuneful bird is a ventriloquist. The seat of the song is in the breast.

The use of the lungs in the system has been said to be obscure: one use however is plain, though, in some sense, external to the system, and that is, the formation, in conjunction with the larynx, of voice and speech.* They are, to animal utterance, what the bellows are to the organ.

For the sake of method, we have considered animal bodies under three divisions: their bones, their muscles, and their vessels; and we have stated our observations upon these parts separately. But this is to diminish the strength of the argument. The wisdom of the Creator is seen, not in their separate but their collective action; in their mutual subserviency and dependence; in their contributing *together* to one effect, and one use. It has been said, that a man cannot lift his hand to his head, without finding enough to convince him of the existence of a God. And it is well said; for he has only to reflect, familiar as

band at this extremity stretched across it, which is furnished from the surrounding parts with muscles to modulate the tone.

* Speech or pronunciation entirely depends on the air passing from the lungs, though at the same time it requires a particular disposition of the vocal tube: for one sort of pronunciation the tongue is the principal agent of formation; for another it is the teeth; others are formed by the lips, whilst, for the production of others, the air must pass the nasal cavities.

this action is, and simple as it seems to be, how many things are requisite for the performing of it: how many things which we understand, to say nothing of many more, probably, which we do not; viz. first, a long, hard, strong cylinder, in order to give to the arm its firmness and tension; but which, being rigid, and in its substance inflexible, can only turn upon joints: secondly, therefore, joints for this purpose, one at the shoulder to raise the arm, another at the elbow to bend it; these joints continually fed with a soft mucilage to make the parts slip easily upon one another, and holden together by strong braces, to keep them in their position: then, thirdly, strings and wires, *i. e.* muscles and tendons, artificially inserted for the purpose of drawing the bones in the directions in which the joints allow them to move. Hitherto we seem to understand the mechanism pretty well; and, understanding this, we possess enough for our conclusion: nevertheless, we have hitherto only a machine standing still; a dead organization—an apparatus. To put the system in a state of activity, to set it at work, a farther provision is necessary, viz. a communication with the brain by means of nerves. We know the existence of this communication, because we can see the communicating threads, and can trace them to the brain: its necessity we also know, because if the thread be cut, if the communication be intercepted, the muscle becomes paralytic: but beyond this we know little, the organization being too minute and subtile for our inspection.*

* The functions of the brain and nervous system are at present involved in much mystery; we see only the surprising effects of their agency. That the mind may act on the body, and indeed superintend the whole fabric, it is necessary that this thinking immaterial agent should be provided with an immediate place of residence: that residence is the brain! And as we are destined to hold correspondence with the material beings that surround us, we must be supplied with organs fitted to receive the different kinds of impressions made upon them. For this purpose we are provided with the organs of sense; the eye is adapted to light; the ear to sound; the nose to smell; the mouth to taste; the skin to touch. But as the brain is the seat or source of sensation and volition, we must be furnished with a medium of communication between the brain and external senses. Hence we are supplied with nerves. An impression received on the most remote part of the body, is propagated by the nerves to the brain, where, cognizance being taken of it, sensation is produced; again, a command emanating from the brain is transmitted along the nervous chords to the parts requisite to be put into motion, when the influence is immediately acknowledged. That these properties reside in the brain and nerves is almost self-evident. By directing my will to the muscles which move my fingers I easily bend them, because there is a direct communication with the brain by means of the nerves: if these be divided I might will my fingers to move, but they would continue motionless. This proves that volition is connected with the brain. Again, if the nerves passing to the limb be divided, the most severe injury may be inflicted on it, yet no pain will be experienced, because the communication with the sensorium has been cut off. When, as in apoplexy or an effusion of blood on the brain, it is compressed, loss of voluntary motion and sensation follows; notwithstanding the involuntary functions may for a time proceed in consequence of the nerves of organic life posessing some inherent and apparently independent power. By means of our nerves we are warned of those bodies which are noxious to us. By means of our nerves we receive all our corporeal enjoyment, and even the powers of the mind are extensively influenced by their actions.

To what has been enumerated, as officiating in the single act of a man's raising his hand to his head, must be added likewise, all that is necessary, and all that contributes to the growth, nourishment, and sustentation of the limb, the repair of its waste, the preservation of its health; such as the circulation of the blood through every part of it; its lymphatics, exhalants, absorbents; its excretions and integuments. All these share in the result; join in the effect; and how all these, or any of them, come together without a designing, disposing intelligence, it is impossible to conceive.

CHAPTER XI.

OF THE ANIMAL STRUCTURE REGARDED AS A MASS.

Contemplating *an animal body* in its collective capacity, we cannot forget to notice, what a number of instruments are brought together, and often within how small a compass. It is a cluster of contrivances. In a canary bird, for instance, and in the single ounce of matter which composes his body, (but which seems to be all employed,) we have instruments for eating, for digesting, for nourishment, for breathing, for generation, for running, for flying, for seeing, for hearing, for smelling, each appropriate,—each entirely different from all the rest.

The human, or indeed the animal frame, considered as a mass or assemblage, exhibits in its composition three properties, which have long struck my mind as indubitable evidences, not only of design, but of a great deal of attention and accuracy in prosecuting the design.

I. The first is, the exact correspondency of the two sides of the same animal; the right hand answering to the left, leg to leg, eye to eye, one side of the countenance to the other; and with a precision, to imitate which in any tolerable degree forms one of the difficulties of statuary, and requires, on the part of the artist, a constant attention to this property of his work, distinct from every other.

It is the most difficult thing that can be to get a wig made even: yet how seldom is the *face* awry! And what care is taken that it should not be so, the anatomy of its bones demonstrates. The upper part of the face is composed of thirteen bones, six on each side, answering each to each, and the thirteenth, without a fellow, in the middle: the lower part of the face is in like manner composed of six bones, three on each side respectively corresponding, and the lower jaw in the centre.*

* The bones which compose the upper part of the face are as follow: viz. Two *ossa nasi*; two *ossa unguis*; two *ossa malarum*;

In building an arch, could more be done in order to make the curve *true*, *i. e.* the parts equi-distant from the middle, alike in figure and position?

The exact resemblance of the *eyes*, considering how compounded this organ is in its structure, how various and how delicate are the shades of colour with which its iris is tinged; how differently, as to effect upon appearance, the eye may be mounted in its socket, and how differently in different heads eyes actually are set,—is a property of animal bodies much to be admired. Of ten thousand eyes, I do not know that it would be possible to match one, except with its own fellow; or to distribute them into suitable pairs by any other selection than that which obtains.

This regularity of the animal structure is rendered more remarkable by the three following considerations:—First, the limbs, *separately* taken, have not this correlation of parts, but the contrary of it. A knife drawn down the chine, cuts the human body into two parts, externally equal and alike; you cannot draw a straight line which will divide a hand, a foot, the leg, the thigh, the cheek, the eye, the ear, into two parts equal and alike. Those parts which are placed upon the middle or partition line of the body, or which traverse that

two *ossa maxillaria superiora;* two *ossa palati;* two *ossa spongiosa inferiora;* and the *vomer*. The lower part of the face consists of the *maxilla inferior*, or lower jaw only; it is evident therefore there must be some error in the preceding enumeration.

line, as the nose, the tongue, the lips, may be so divided, or, more properly speaking, are double organs; but other parts cannot. This shows that the correspondency which we have been describing, does not arise by any necessity in the nature of the subject: for, if necessary, it would be universal; whereas it is observed only in the system or assemblage; it is not true of the separate parts; that is to say, it is found where it conduces to beauty or utility; it is not found where it would subsist at the expense of both. The two wings of a bird always correspond: the two sides of a feather frequently do not. In centipedes, millepedes, and that whole tribe of insects, no two legs on the same side are alike; yet there is the most exact parity between the legs opposite to one another.*

2. The next circumstance to be remarked is, that whilst the cavities of the body are so configurated, as *externally* to exhibit the most exact correspondency of the opposite sides, the contents of these cavities have no such correspondency. A line drawn down the middle of the breast, di-

* The celebrated Bichat observes that the organs of *animal life* are *symmetrical.* "Two globes, similar in every respect, receive the impressions of light. Sounds and odours have also their double analagous organ. A single membrane is affected by savours, but the median line is manifest upon it." There are indications throughout the whole body, and numerous distinct points which demonstrate the symmetry of the animal life of man, and every class of animal existence.

vides the thorax into two sides exactly similar; yet these two sides enclose very different contents. The heart lies on the left side; a lobe of the lungs on the right; balancing each other neither in size nor shape. The same thing holds of the abdomen. The liver lies on the right side,* without any similar viscus opposed to it on the left. The spleen indeed is situated over against the liver; but agreeing with the liver neither in bulk nor form. There is no equipollency between these. The stomach is a vessel, both irregular in its shape, and oblique in its position. The foldings and doublings of the intestines do not present a parity of sides. Yet that symmetry which depends upon the correlation of the sides, is externally preserved throughout the whole trunk; and is the more remarkable in the lower parts of it, as the integuments are soft; and the shape, consequently, is not, as the thorax is by its ribs, reduced by natural stays. It is evident, therefore, that the external proportion does not arise from any equality in the shape or pressure of the internal contents.† What is it indeed but a correction of inequalities? an adjustment, by mutual compensation, of anomalous forms into a regular congeries? the effect, in

* The principle lobe of the liver is on the right, but a smaller is extended into the left side. See TAB. XXII.

† The viscera of the thorax and abdomen, *i. e.* the viscera of *organic life*, are *irregularly* disposed. The *agents of volition* are double, but the instruments of *involuntary motion*, namely the interior life, are single, and at least are irregular in their form.

a word, of artful, and, if we might be permitted so to speak, of studied collocation?

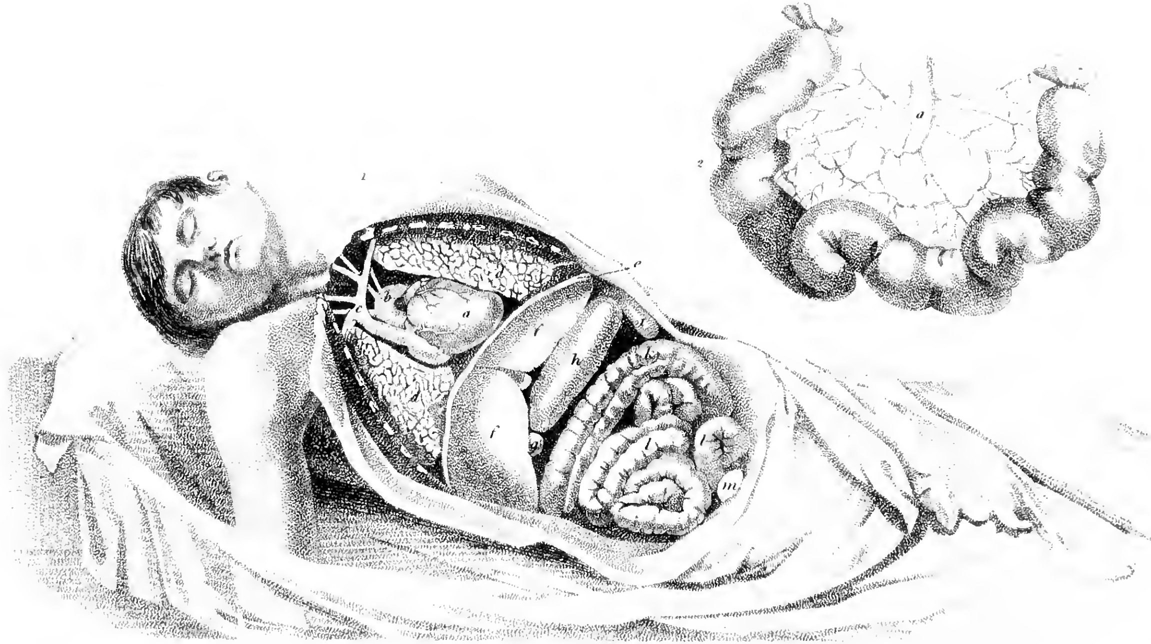
3. Similar also to this, is the third observation; that an internal inequality in the feeding vessels is so managed, as to produce no inequality in parts which were intended to correspond. The right arm answers accurately to the left, both in size and shape; but the arterial branches, which supply the two arms, do not go off from their trunk, in a pair, in the same manner, at the same place, or at the same angle. Under which want of similitude, it is very difficult to conceive how the same quantity of blood should be pushed through each artery: yet the result is right; the two limbs, which are nourished by them, perceive no difference of supply, no effects of excess or deficiency.

Concerning the difference of manner, in which the subclavian and carotid arteries, upon the different sides of the body, separate themselves from the aorta, Cheselden seems to have thought, that the advantage which the left gain by going off at an angle much more acute than the right, is made up to the right by their going off together in one branch. It is very possible that this may be the compensating contrivance; and if it be so, how curious, how hydrostatical!*

II. Another perfection of the animal mass is

* The arrangement of these vessels is seen in TAB. XVII. *k*, the *right subclavian*; *l*, the *right carotid* arteries, originating from one common trunk; *m*, the *left carotid*; *n*, the *left subclavian*.

TAB. XXII



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*package.** I know nothing which is so surprising. Examine the contents of the trunk of any large animal. Take notice how soft, how tender, how intricate they are; how constantly in action, how necessary to life! Reflect upon the danger of any injury to their substance, any derangement of their position, any obstruction to their office. Observe the heart pumping at the centre, at the rate of eighty strokes in a minute: one set of pipes carrying the stream away from it, another set bringing, in its course, the fluid back to it again; the lungs performing their elaborate office, viz. distending and contracting their many thousand vesicles, by a reciprocation which cannot cease for a minute; the stomach exercising its powerful chemistry; the bowels silently propelling the changed aliment; collecting from it, as it proceeds, and transmitting to the blood an incessant supply of prepared and assimilated nourishment; that blood pursuing its course; the liver, the kidneys, the pancreas, the parotid, with many other known and distinguishable glands, drawing off

* Tab. XXII. Fig. 1. In this plate the parietes of the chest and abdomen, with the omentum, are removed to shew the viscera *in situ*; *a*, the *heart*; *b*, the *aorta*; *c*, the *descending vena cava*; *d*, *d*, the *lungs* divided by the mediastinum into two portions; three lobes belong to the right, and two to the left portion of the lungs; *e*, the *diaphragm*, or that muscle which separates the thorax from the abdomen; *f*, the *liver*; *g*, the *gall-bladder*; *h*, the *stomach*; *i*, the *spleen*; *k*, *k*, the *large intestine*; *l*, *l*, the *small intestines*; *m*, the *bladder*.

from it, all the while, their proper secretions. These several operations, together with others more subtile but less capable of being investigated, are going on within us, at one and the same time. Think of this; and then observe how the body itself, the case which holds this machinery, is rolled, and jolted, and tossed about, the mechanism remaining unhurt, and with very little molestation, even of its nicest motions. Observe a rope-dancer, a tumbler, or a monkey: the sudden inversions and contortions which the in-internal parts sustain by the postures into which their bodies are thrown; or rather observe the shocks which these parts, even in ordinary subjects, sometimes receive from falls and bruises, or by abrupt jerks and twists, without sensible, or with soon-recovered damage. Observe this, and then reflect how firmly every part must be secured, how carefully surrounded, how well tied down and packed together.

This property of animal bodies has never, I think, been considered under a distinct head, or so fully as it deserves. I may be allowed, therefore, in order to verify my observation concerning it, to set forth a short anatomical detail, though it oblige me to use more technical language than I should wish to introduce into a work of this kind.

1. The *heart* (such care is taken of the centre of life) is placed between the soft lobes of the lungs;

tied to the mediastinum* and to the pericardium; which pericardium is not only itself an exceedingly strong membrane, but *adheres* firmly to the duplicature of the mediastinum, and, by its point, to the middle tendon of the diaphragm. The heart is also *sustained* in its place by the great blood-vessels which issue from it.

2. The *lungs* are *tied* to the sternum by the mediastinum, before; to the vertebræ by the pleura, behind. It seems indeed to be the very use of the mediastinum (which is a membrane that goes straight through the middle of the thorax, from the breast to the back) to keep the contents of the thorax in their places; in particular, to hinder one portion of the lungs from incommoding another, or the parts of the lungs from pressing upon each other when we lie on one side.†

3. The *liver* is fastened in the body by two ligaments; the first, which is large and strong, comes from the covering of the diaphragm, and penetrates the substance of the liver; the second is the umbilical vein, which, after birth, degenerates into a ligament. The first, which is the principal, fixes the liver in its situation, whilst the body holds an erect posture; the second prevents

* The mediastinum is a membrane which divides the chest into two parts.

† A membrane, called the pleura, lines the chest and covers its contents: on each side it forms a distinct bag for the lungs, and the lungs of opposite sides being independent, breathing may be continued in one lung, though the other has been destroyed.

it from pressing upon the diaphragm when we lie down; and both together *sling* or suspend the liver when we lie upon our backs, so that it may not compress or obstruct the ascending vena cava, to which belongs the important office of returning the blood from the body to the heart.

4. The *bladder* is tied to the naval by the urachus, transformed into a ligament: thus, what was a passage for urine to the fœtus, becomes, after birth, a support or stay to the bladder. The peritonæum* also keeps the viscera from confounding themselves with, or pressing irregularly upon, the bladder: for the kidneys and bladder are contained in a distinct duplicature of that membrane, being thereby partitioned off from the other contents of the abdomen.

5. The *kidneys* are lodged in a bed of fat.

6. The *pancreas*, or sweetbread, is strongly tied to the peritonæum, which is the great wrapping sheet, that encloses all the viscera contained in the lower belly.

7. The *spleen* also is confined to its place by an adhesion to the peritonæum and diaphragm, and

* The *peritonæum* is a smooth shining membrane enveloping the liver, stomach, spleen, and intestines; the kidneys and bladder are partially covered by it. The lower surface of the diaphragm, and the parietes or sides of the abdomen, receive their exterior covering from it. The inner surface habitually exhales a moisture which bedews the surface of the several organs, permits motion, and prevents adhesion. The mesentery, the broad ligament of the liver, and the omentum, are productions or folds of the same membrane.

by a connexion with the omentum. It is possible, in my opinion, that the spleen may be merely a *stuffing*, a soft cushion to fill up a vacancy or hollow, which, unless occupied, would leave the package loose and unsteady: for, supposing that it answers no other purpose than this, it must be vascular, and admit of a circulation through it, in order to be kept alive, or be a part of a living body.*

8. The *omentum*,† epiploon, or cawl, is an apron tucked up, or doubling upon itself, at its lowest part. The upper edge is tied to the bottom of the stomach, to the spleen, as hath already been observed, and to part of the duodenum. The reflected edge also, after forming the doubling, comes up behind the front flap, and is tied to the colon ‡ and adjoining viscera.

9. The septa of the brain probably prevent one part of that organ from pressing with too great a weight upon another part. The processes of the

* The several viscera are correctly described, and sufficient is said for the purposes for which they are introduced. To the supposed use of the *spleen* only an objection must be taken: various hypotheses have been entertained as to its office, but none are perfectly conclusive; the most probable is, that it is a source of supply of blood for furnishing the gastric secretion, or that the blood undergoes some important change in it. See note, p. 59.

† The omentum is spread over the intestines, and is formed of a duplicature of the peritonæum with more or less of fat interposed; indeed it receives the superfluous depositions of fat. Like other parts of the peritonæum it is an exhaling organ for producing the fluid necessary for the due action and condition of the intestines.

‡ The upper portion of the large intestine.

dura mater divide the cavity of the skull, like so many inner partition walls, and thereby confine each hemisphere and lobe of the brain to the chamber which is assigned to it, without its being liable to rest upon, or incommode the neighbouring parts. The great art and caution of packing is to prevent one thing hurting another. This, in the head, the chest, and the abdomen, of an animal body, is, amongst other methods, provided for by membranous partitions and wrappings, which keep the parts separate.

The above may serve as a short account of the manner in which the principal viscera are sustained in their places. But of the provisions for this purpose, by far, in my opinion, the most curious, and where also such a provision was most wanted, is in the *guts*. It is pretty evident, that a long narrow tube (in man, about five times the length of the body) laid from side to side in folds upon one another, winding in oblique and circuitous directions, composed also of a soft and yielding substance, must, without some extraordinary precaution for its safety, be continually displaced by the various, sudden, and abrupt motions of the body which contains it. I should expect that, if not bruised or wounded by every fall, or leap, or twist, it would be entangled, or be involved with itself, or, at the least, slipped and shaken out of the order in which it is disposed, and which order is necessary to be preserved for the carrying on of the important functions which it has to execute in the animal economy. Let us see, therefore, how a danger so serious, and yet so natural to the length, narrowness, and tubular form of the part, is provided against. The expedient is admirable; and it is this; the intestinal canal, throughout its whole progress, is knit to the edge of a broad fat membrane called the *mesentery*.* It forms the margin of this mesentery, being stitched and fastened to it like the edging of a ruffle: being four times as long as the mesentery itself, it is what a sempstress would call "puckered or gathered on" to it. This is the nature of the connexion of the gut with the mesentery; and being thus joined to, or rather made a part of the mesentery, it is folded and wrapped up together with it. Now the mesentery, having a considerable dimension in breadth, being in its substance, withal, both thick and suety, is capable of a close and safe folding, in comparison of what the intestinal tube would admit of, if it had remained loose. The mesentery, likewise, not only keeps the intestinal canal in its proper place and position, under all the turns and windings of its course, but sustains the numberless small vessels, the arteries, the veins, the lymphe-

* TAB. XXII. Fig. 2. This membrane is formed by a reflection of the *peritonæum* from each side of the vertebræ; it connects the intestines loosely to the spine, to allow them a certain degree of motion, yet retains them in their places; and furnishes their exterior covering. Between the laminæ of *a*, the *mesentery*, are received the *glands, vessels, and nerves;* and its extent admits of a proper distribution of each.

ducts, and, above all, the lacteals, which lead from or to almost every point of its coats and cavity. This membrane, which appears to be the great support and security of the alimentary apparatus, is itself strongly tied to the first three vertebræ of the loins.

III. A third general property of animal forms is *beauty*. I do not mean relative beauty, or that of one individual above another of the same species, or of one species compared with another species; but I mean, generally, the provision which is made in the body of almost every animal, to adapt its appearance to the perception of the animals with which it converses. In our own species, for example, only consider what the parts and materials are, of which the fairest body is composed; and no farther observation will be necessary to show, how well these things are wrapped up, so as to form a mass, which shall be capable of symmetry in its proportion, and of beauty in its aspect; how the bones are covered, the bowels concealed, the roughnesses of the muscles smoothed and softened; and how over the whole is drawn an integument, which converts the disgusting materials of a dissecting-room into an object of attraction to the sight, or one upon which it rests, at least, with ease and satisfaction. Much of this effect is to be attributed to the intervention of the cellular or adipose membrane,* which lies imme-

* The *cellular membrane* is a system of considerable extent

diately under the skin; is a kind of lining to it; is moist, soft, slippery, and compressible; every where filling up the interstices of the muscles, and forming thereby the roundness and flowing line, as well as the evenness and polish of the whole surface.

All which seems to be a strong indication of design, and of a design studiously directed to this purpose. And it being once allowed, that such a purpose existed with respect to *any* of the productions of nature, we may refer, with a considerable degree of probability, other particulars to the same intention; such as the teints of flowers, the plumage of birds, the furs of beasts, the bright scales of fishes, the painted wings of butterflies and beetles, the rich colours and spotted lustre of many tribes of insects.

every where continuous, surrounding and penetrating the multitude of organic formations; it consists of whitish filaments interlaced and intermixed a thousand different ways, leaving between them certain interstices for the reception of *fat* or *serum*; it is a tissue of fibres which constitutes the bond that unites the various parts of the animal fabric, and the medium which separates them.

In this " cellular or adipose" tissue the fat or adipose substance is deposited. Certainly its presence beneath the skin, by rounding the outline beautifies the form; but in the animal economy it has other and more important uses. First, by forming elastic cushions or layers which render the pressure exerted on the skin less severe. Secondly, by receiving into its cells the surplus of nutritive matter, to be brought out and employed according to the exigence, in instances where food cannot be obtained, and in often supporting the system under wasting diseases, until, by medical treatment, or the powers of nature, the deranged functions are put in order. Thirdly, as all fat bodies are bad conductors of caloric, so it contributes to the preservation of the heat of the body. Persons of a full habit in general suffer little in winter from cold.

There are parts also of animals ornamental, and the properties by which they are so, not subservient, that we know of, to any other purpose. The *irides* of most animals are very beautiful, without conducing at all, by their beauty, to the perfection of vision: and nature could in no part have employed her pencil to so much advantage, because no part presents itself so conspicuously to the observer, or communicates so great an effect to the whole aspect.

In plants, especially in the flowers of plants, the principle of beauty holds a still more considerable place in their composition; is still more confessed than in animals. Why, for one instance out of a thousand, does the corolla of the tulip, when advanced to its size and maturity, change its colour? The purposes, so far as we can see, of vegetable nutrition, might have been carried on as well by its continuing green. Or, if this could not be, consistently with the progress of vegetable life, why break into such a variety of colours? This is no proper effect of age, or of declension in the ascent of the sap; for that, like the autumnal teints, would have produced one colour on one leaf, with marks of fading and withering. It seems a lame account to call it, as it has been called, a disease of the plant. Is it not more probable, that this property, which is independent, as it should seem, of the wants and utilities of the plant, was calculated for beauty, intended for display?

A ground, I know, of objection, has been taken against the whole topic of argument, namely, that there is no such thing as beauty at all; in other words, that whatever is useful and familiar, comes of course to be thought beautiful; and that things appear to be so, only by their alliance with these qualities. Our idea of beauty is capable of being in so great a degree modified by habit, by fashion, by the experience of advantage or pleasure, and by associations arising out of that experience, that a question has been made, whether it be not altogether generated by these causes, or would have any proper existence without them. It seems, however, a carrying of the conclusion too far, to deny the existence of the principle, viz. a native capacity of perceiving beauty, on account of an influence, or of varieties proceeding from that influence, to which it is subject, seeing that principles the most acknowledged are liable to be affected in the same manner. I should rather argue thus: The question respects objects of sight. Now every other sense hath its distinction of agreeable and disagreeable. Some tastes offend the palate, others gratify it. In brutes and insects, this distinction is stronger and more regular than in man. Every horse, ox, sheep, swine, when at liberty to choose, and when in a natural state, that is, when not vitiated by habits forced upon it, eats and rejects the same plants. Many insects which feed upon particular plants, will rather die than change their appropriate leaf. All this looks like a determination in the sense itself to particular tastes. In like manner, smells affect the nose with sensations pleasurable or disgusting. Some sounds, or compositions of sound, delight the ear; others torture it. Habit can do much in all these cases, (and it is well for us that it can; for it is this power which reconciles us to many necessities;) but has the distinction, in the mean time, of agreeable and disagreeable, no foundation in the sense itself? What is true of the other senses, is most probably true of the eye, (the analogy is irresistible,) viz. that there belongs to it an original constitution, fitted to receive pleasure from some impressions, and pain from others.

I do not however know, that the argument which alleges beauty as a final cause, rests upon this concession. We possess a sense of beauty, however we come by it. It in fact exists. Things are not indifferent to this sense; all objects do not suit it; many, which we see, are agreeable to it; many others disagreeable. It is certainly not the effect of habit upon the particular object, because the most agreeable objects are often the most rare; many, which are very common, continue to be offensive. If they be made supportable by habit, it is all which habit can do; they never become agreeable. If this sense, therefore, be acquired, it is a result; the produce of numerous and complicated actions of external objects upon the senses, and of the mind upon its sensations. With this *result*, there must be a certain congruity to enable any particular object to please: and that congruity, we contend, is consulted in the *aspect* which is given to animal and vegetable bodies.

IV. The skin and covering of animals is that upon which their appearance chiefly depends, and it is that part which, perhaps, in all animals is most decorated, and most free from impurities. But were beauty, or agreeableness of aspect, entirely out of the question, there is another purpose answered by this integument, and by the collocation of the parts of the body beneath it, which is of still greater importance; and that purpose is *concealment*.* Were it possible to view through the skin the mechanism of our bodies, the sight would frighten us out of our wits. " Durst we make a single movement," asks a lively French writer, " or stir a step from the place we were in, if we *saw* our blood circulating, the tendons pulling, the lungs blowing, the humours filtrating, and all the incomprehensible assemblage of fibres, tubes, pumps, valves, currents, pivots, which sustain an existence at once so frail, and so presumptuous?"

V. Of animal bodies, considered as masses, there is another property, more curious than it is

* The purpose of integuments is, we conceive, *protection* rather than *concealment*; it is an elastic medium resisting every violence better than any other medium. See also preceding note, p. 204.

generally thought to be; which is the faculty of *standing*: and it is more remarkable in two-legged animals than in quadrupeds, and, most of all, as being the tallest, and resting upon the smallest base, in man.* There is more, I think, in the matter than we are aware of. The statue of a man, placed loosely upon its pedestal, would not be secure of standing half an hour. You are obliged to fix its feet to the block by bolts and solder; or the first shake, the first gust of wind, is sure to throw it down. Yet this statue shall express all the mechanical proportions of a living model. It is not, therefore, the mere figure, or merely placing the centre of gravity within the base, that is sufficient. Either the law of gravitation is suspended in favour of living substances, or something more is done for them, in order to enable them to uphold their posture. There is no reason whatever to doubt, but that their parts descend by gravitation in the same manner as those of dead matter. The gift, therefore, appears to me to consist in a faculty of perpetually shifting

* Anatomy explains the mode in which the weight of the body is transmitted to the feet, and we have seen that the muscles which prevent the head from falling forward in standing, have their fixed point in the neck; that those which perform the same office with regard to the vertebral column, have theirs in the pelvis; that those which preserve the pelvis in equilibrium are attached to the thighs, or to the bones of the legs; that those which prevent the thighs from falling backward are inserted into the tibia; and lastly, that those that preserve the tibia in their vertical position have their fixed point in the feet; these preserve us firm in a standing position.

the centre of gravity, by a set of obscure, indeed, but of quick-balancing actions, so as to keep the line of direction, which is a line drawn from that centre to the ground, within its prescribed limits. Of these actions it may be observed, first, that they in part constitute what we call strength. The dead body drops down. The mere adjustment, therefore, of weight and pressure, which may be the same the moment after death as the moment before, does not support the column. In cases also of extreme weakness, the patient cannot stand upright. Secondly, that these actions are only in a small degree voluntary. A man is seldom conscious of his voluntary powers in keeping himself upon his legs. A child learning to walk is the greatest posture-master in the world: but art, if it may be so called, sinks into habit; and he is soon able to poise himself in a great variety of attitudes, without being sensible either of caution or effort. But still there must be an aptitude of parts, upon which habit can thus attach; a previous capacity of motions which the animal is thus taught to exercise: and the facility with which this exercise is acquired forms one object of our admiration. What parts are principally employed, or in what manner each contributes its office, is, as hath already been confessed, difficult to explain. Perhaps the obscure motion of the bones of the feet may have their share in this effect. They are put in action by every slip or vacillation of the body, and seem to assist in restoring its balance. Certain it is, that this circumstance in the structure of the foot, viz. its being composed of many small bones, applied to, and articulating with one another, by diversely shaped surfaces, instead of being made of one piece, like the last of a shoe, is very remarkable.* I suppose also, that it would be difficult to stand firmly upon stilts or wooden legs, though their base exactly imitated the figure and dimensions of the sole of the foot. The alternation of the joints, the knee-joint bending backward, the hip-joint forward; the flexibility, in every direction, of the spine, especially in the loins and neck, appear to be of great moment in preserving the equilibrium of the body. With respect to this last circumstance, it is observable, that the vertebræ are so confined by ligaments, as to allow no more slipping upon their bases, than what is just sufficient to break the shock which any violent

* See Tab. XI. There is no part of the human frame which is more wonderfully constructed than the foot. It has the requisite strength to support the weight of the body, and often an additional burden; flexibility, that it may be adapted to the inequalities of the surface on which we tread: and elasticity, to assist in walking, running, and springing from the ground. This advantage we possess from the number of joints, the arch of the foot being composed of twenty-six bones. These bones have a considerable play on each other; and as each articulating surface is covered with cartilage, the essential property of which is *elasticity*, the jarring is thus prevented which would result from a contact of the bones.

"The first question which naturally arises, is, Why there should be so many bones? the answer is—In order that there may be so many joints; for the structure of a joint not only permits motion but bestows elasticity."

motion may occasion to the body. A certain degree also of tension of the sinews appears to be essential to an erect posture; for it is by the loss of this, that the dead or paralytic body drops down. The whole is a wonderful result of combined powers, and of very complicated operations. Indeed, that *standing* is not so simple a business as we imagine it to be, is evident from the strange gesticulations of a drunken man, who has lost the government of the centre of gravity.

We have said that this property is the most worthy of observation in the *human* body: but a *bird*, resting upon its perch, or hopping upon a spray, affords no mean specimen of the same faculty. A chicken runs off as soon as it is hatched from the egg; yet a chicken, considered geometrically, and with relation to its centre of gravity, its line of direction, and its equilibrium, is a very irregular solid. Is this gift, therefore, or instruction? May it not be said to be with great attention, that nature hath balanced the body upon its pivots?

I observe also in the same *bird* a piece of useful mechanism of this kind. In the trussing of a fowl, upon bending the legs and thighs up towards the body, the cook finds that the claws close of their own accord. Now let it be remembered, that this is the position of the limbs, in which the bird rests upon its perch. And in this position it sleeps in safety; for the claws do their office in keeping hold of the support, not by any exertion of voluntary power, which sleep might suspend, but by the traction of the tendons in consequence of the attitude which the legs and thighs take by the bird sitting down, and to which the mere weight of the body gives the force that is necessary.

VI. Regarding the human body as a mass; regarding the general conformations which obtain in it; regarding also particular parts in respect to those conformations; we shall be led to observe what I call "interrupted analogies." The following are examples of what I mean by these terms; and I do not know how such critical deviations can, by any possible hypothesis, be accounted for without design.

1. All the bones of the body are covered with a *periosteum*,* except the teeth; where it ceases, and an enamel of ivory, which saws and files will hardly touch, comes into its place.† No one can doubt of the use and propriety of this difference; of the "analogy" being thus "interrupted;" of the rule, which belongs to the conformation of

* The *periosteum* consists of layers of condensed cellular tissue, which constitute a membrane surrounding all the bones, except in such parts as are covered with cartilage; it is connected to them by innumerable vessels which nourish the external plates.

† "Enamel" is a substance harder than iron; it is only found round the crown of the tooth, or those parts which we see exposed. It is thick on the upper surface, and gradually thinner as it draws near the root. This structure and disposition of it is a provision indispensable in order to give strength and to allow of attrition.

the bones, stopping where it does stop; for, had so exquisitely sensible a membrane as the periosteum invested the teeth, as it invests every other bone of the body, *their* action, necessary exposure, and irritation, would have subjected the animal to continual pain. General as it is, it was not the sort of integument which suited the teeth: what they stood in need of, was a strong, hard, insensible, defensive coat; and exactly such a covering is given to them, in the ivory enamel which adheres to their surface.

2. The scarf-skin, which clothes all the rest of the body, gives way, at the extremities of the toes and fingers, to *nails*. A man has only to look at his hand, to observe with what nicety and precision that covering, which extends over every other part, is here superseded by a different substance, and a different texture. Now, if either the rule had been necessary, or the deviation from it accidental, this effect would not be seen. When I speak of the rule being necessary, I mean the formation of the skin upon the surface being produced by a set of causes constituted without design, and acting, as all ignorant causes must act, by a general operation. Were this the case, no account could be given of the operation being suspended at the fingers' ends, or on the back part of the fingers, and not on the fore part. On the other hand, if the deviation were accidental, an error, an anomalism; were it any thing

else than settled by intention; we should meet with nails upon other parts of the body. They would be scattered over the surface, like warts or pimples.

3. All the great cavities of the body are enclosed by membranes, except the *skull*. Why should not the brain be content with the same covering as that which serves for the other principal organs of the body? The heart, the lungs, the liver, the stomach, the bowels, have all soft integuments, and nothing else. The muscular coats are all soft and membranous. I can see a reason for this distinction in the final cause, but in no other. The importance of the brain to life, (which experience proves to be immediate,) and the extreme tenderness of its substance, make a solid case more necessary for it than for any other part: and such a case the hardness of the skull supplies. When the smallest portion of this natural casket is lost, how carefully, yet how imperfectly, is it replaced by a plate of metal! If an anatomist should say, that this bony protection is not confined to the brain, but is extended along the course of the spine, I answer, that he adds strength to the argument. If he remark, that the chest also is fortified by bones, I reply, that I should have alleged this instance myself, if the ribs had not appeared subservient to the purpose of motion as well as of defence. What distinguishes the skull from every other cavity is, that the bony covering completely

surrounds its contents, and is calculated, not for motion, but solely for defence.* Those hollows, likewise, and inequalities, which we observe in the inside of the skull, and which exactly fit the folds of the brain, answer the important design of keeping the substance of the brain steady, and of guarding it against concussions.

CHAPTER XII.

COMPARATIVE ANATOMY.

Whenever we find a general plan pursued, yet with such variations in it as are, in each case, required by the particular exigency of the subject to which it is applied, we possess, in such plan and such adaptation, the strongest evidence that can be afforded of intelligence and design; an evidence

* From the importance of the brain as being the material instrument of thought, and on account of its very delicate texture, it was necessary that it should be especially guarded from physical derangement, and defended against injuries from surrounding bodies; and we admit that the skull is the most effective security; particularly on account of its form. Mr. Bell terms it an *elliptical dome*, but strictly speaking it is a *spheroid*, so that all pressure or blows upon the head are distributed in all directions, from the point of the bone struck over the other parts, and consequently falls less injuriously on the brain. Nature has been further provident, for amongst the protecting parts we may also reckon the hair, the scalp, the muscles, and the pericranium. The hair too being a bad conductor of caloric is well suited to preserve an uniform temperature in the head.

which most completely excludes every other hypothesis. If the general plan proceeded from any fixed necessity in the nature of things, how could it accommodate itself to the various wants and uses which it had to serve under different circumstances, and on different occasions? *Arkwright's* mill was invented for the spinning of cotton. We see it employed for the spinning of wool, flax, and hemp, with such modifications of the original principle, such variety in the same plan, as the texture of those different materials rendered necessary. Of the machine's being put together with design, if it were possible to doubt, whilst we saw it only under one mode, and in one form; when we came to observe it in its different applications, with such changes of structure, such additions, and supplements, as the special and particular use in each case demanded, we could not refuse any longer our assent to the proposition, "that intelligence, properly and strictly so called, (including under that name, foresight, consideration, reference to utility,) had been employed, as well in the primitive plan, as in the several changes and accommodations which it is made to undergo."

Very much of this reasoning is applicable to what has been called *Comparative Anatomy.** In their general economy, in the outlines of the plan,

* "Comparative Anatomy;" so called from comparing with Human Anatomy, the points of similarity and dissimilarity observed in inferior animals.

in the construction as well as offices of their principal parts, there exists between all large terrestrial animals a close resemblance. In all life is sustained, and the body nourished by nearly the same apparatus. The heart, the lungs, the stomach, the liver, the kidneys, are much alike in all. The same fluid (for no distinction of blood has been observed) circulates through their vessels, and nearly in the same order. The same cause, therefore, whatever that cause was, has been concerned in the origin, has governed the production of these different animal forms.

When we pass on to smaller animals, or to the inhabitants of a different element, the resemblance becomes more distant and more obscure; but still the plan accompanies us.

And, what we can never enough commend, and which it is our business at present to exemplify, the plan is attended, through all its varieties and deflections, by subserviencies to special occasions and utilities.

I. The *covering* of different animals (though whether I am correct in classing this under their anatomy, I do not know) is the first thing which presents itself to our observation; and is, in truth, both for its variety, and its suitableness to their several natures, as much to be admired as any part of their structure. We have bristles, hair, wool, furs, feathers, quills, prickles, scales;* yet in

* "Hair" is found on all the mammalia, whales not excepted,

this diversity both of material and form, we cannot change one animal's coat for another, without evidently changing it for the worse; taking care however to remark, that these coverings are, in many cases, armour as well as clothing; intended for protection as well as warmth.

The *human* animal is the only one which is naked, and the only one which can clothe itself. This is one of the properties which renders him an animal of all climates, and of all seasons. He can adapt the warmth or lightness of his covering to the temperature of his habitation. Had he been born with a fleece upon his back, although he might have been comforted by its warmth in high latitudes, it would have oppressed him by its weight and heat as the species spread towards the equator.

What art, however, does for men, nature has, in many instances, done for those animals which are incapable of art. Their clothing, of its own accord, changes with their necessities. This is particularly

differing however greatly in quantity according to the species, but always most abundant in those parts exposed, and on those animals which inhabit cold countries. It is found on birds along with feathers on different parts of the neck. It is absent in the reptiles, fishes, and mollusca.

"Feathers" occur on birds only, and characterize the class—they are related to the hairs in the animal economy in regard to situation, composition, and purpose; they are renewed periodically, or if accidentally destroyed are readily reproduced.

"Quills, prickles, and scales" are chiefly formed for the defence of the animals which possess them. See Flemming's Philosophy of Zoology, vol. i p. 80.

the case with that large tribe of quadrupeds which are covered with *furs*. Every dealer in hare-skins and rabbit-skins, knows how much the fur is thickened by the approach of winter. It seems to be a part of the same constitution and the same design, that wool in hot countries, degenerates, as it is called, but in truth (most happily for the animal's ease) passes into hair; whilst, on the contrary, that hair, on the dogs of the polar regions, is turned into wool, or something very like it. To which may be referred, what naturalists have remarked, that bears, wolves, foxes, hares, which do not take the water, have the fur much thicker on the back than the belly: whereas in the beaver it is the thickest upon the belly; as are the feathers on water-fowl. We know the final cause of all this; and we know no other.

The *covering of birds* cannot escape the most vulgar observation. Its lightness, its smoothness, its warmth;—the disposition of the feathers all inclined backward, the down about their stem, the overlapping of their tips, their different configuration in different parts, not to mention the variety of their colours, constitute a vestment for the body, so beautiful, and so appropriate to the life which the animal is to lead, as that, I think, we should have had no conception of any thing equally perfect, if we had never seen it, or can now imagine any thing more so. Let us suppose (what is possible only in supposition) a person who had never seen a bird, to be presented with a plucked pheasant, and bid to set his wits to work, how to contrive for it a covering which shall unite the qualities of warmth, levity, and least resistance to the air, and the highest degree of each; giving it also as much of beauty and ornament as he could afford. He is the person to behold the work of the Deity, in this part of his creation, with the sentiments which are due to it.

The commendation, which the general aspect of the feathered world seldom fails of exciting, will be increased by farther examination. It is one of those cases in which the philosopher has more to admire than the common observer. Every *feather* is a mechanical wonder. If we look at the quill, we find properties not easily brought together—strength and lightness. I know few things more remarkable than the strength and lightness of the very pen with which I am writing. If we cast our eye to the upper part of the stem, we see a material, made for the purpose, used in no other class of animals, and in no other part of birds; tough, light, pliant, elastic. The pith, also, which feeds the feathers, is, amongst animal substances, *sui generis;* neither bone, flesh, membrane, nor tendon.*

* The quill part of a feather is composed of circular and longitudinal fibres. In making a pen, you must scrape off the coat of circular fibres, or the quill will split in a ragged, jagged manner, making what boys call *cat's teeth*.

But the artificial part of a feather is the *beard*, or, as it is sometimes, I believe, called, the vane. By the beards are meant, what are fastened on each side of the stem, and what constitute the breadth of the feather; what we usually strip off from one side or both, when we make a pen. The separate pieces of laminæ, of which the beard is composed, are called threads, sometimes filaments, or rays. Now the first thing which an attentive observer will remark is, how much stronger the beard of the feather shows itself to be, when pressed in a direction perpendicular to its plane, than when rubbed, either up or down, in the line of the stem; and he will soon discover the structure which occasions this difference, viz. that the laminæ, whereof these beards are composed, are flat, and placed with their flat sides towards each other; by which means, whilst they *easily* bend for the approaching of each other, as any one may perceive by drawing his finger ever so lightly upwards, they are much harder to bend out of their plane, which is the direction in which they have to encounter the impulse and pressure of the air, and in which their strength is wanted and put to the trial.

This is one particularity in the structure of a feather; a second is still more extraordinary. Whoever examines a feather, cannot help taking notice, that the threads or laminæ, of which we have been speaking, in their natural state *unite*;

that there union is something more than the mere apposition of loose surfaces; that they are not parted asunder without some degree of force; that nevertheless there is no glutinous cohesion between them; that, therefore, by some mechanical means or other, they catch or clasp among themselves, thereby giving to the beard or vane its closeness and compactness of texture. Nor is this all: when two laminæ, which have been separated by accident or force, are brought together again, they immediately *reclasp;* the connexion, whatever it was, is perfectly recovered, and the beard of the feather becomes as smooth and firm as if nothing had happened to it. Draw your finger down the feather, which is against the grain, and you break probably the junction of some of the contiguous threads; draw your finger up the feather, and you restore all things to their former state. This is no common contrivance: and now for the mechanism by which it is effected.* The threads or laminæ above mentioned, are *interlaced* with one another; and the interlacing is performed by means of a vast number of fibres, or teeth, which the laminæ shoot forth *on each side*, and which hook and grapple together. A friend of mine

* By the aid of the microscope it appears, that the laminæ are not flat, as they appear to the unassisted eye, but are semi-tubular, having on their outward edge a series of bristles, termed in the text fibres, set in pairs opposite one another, which clasp with the bristles of the approximate laminæ, and cause that adhesiveness observable between the several laminæ of the vane.

counted fifty of these fibres in one-twentieth of an inch. These fibres are crooked; but curved after a different manner: for those which proceed from the thread on the side towards the extremity of the feather, are longer, more flexible, and bent downward; whereas those which proceed from the side towards the beginning, or quill-end of the feather, are shorter, firmer, and turn upwards. The process then which takes place is as follows: When two laminæ are pressed together, so that these long fibres are forced far enough over the short ones, *their* crooked parts fall into the cavity made by the crooked parts of the others; just as the latch that is fastened to a door enters into the cavity of the catch fixed to the door-post, and there hooking itself, *fastens* the door; for it is properly in this manner, that one thread of a feather is fastened to the other.

This admirable structure of the feather, which it is easy to see with the microscope,* succeeds perfectly for the use to which nature has designed it; which use was, not only that the laminæ might be united, but that when one thread or lamina has been separated from another by some external vio-

* The appearance they then present is exhibited in Tab. XXIII. Fig, 2. which shews distinctly the form, direction and relative positions of each set of fibrils and the manner in which they lay hold of each other. Those marked *a*, *a*, are branched and tufted, and bend downwards; while those marked *b*, *b*, proceeding from the other side of the lamina, are shorter and firmer and do not divide into branches. See Annuales des Sciences Naturales, Vol. ix, p. 113.

lence, it might be reclasped with sufficient facility and expedition.*

In the *ostrich*, this apparatus of crotchets and fibres, of hooks and teeth, is wanting: and we see the consequence of the want. The filaments hang loose and separate from one another, forming only a kind of down; which constitution of the feathers, however it may fit them for the flowing honours of a lady's head-dress, may be reckoned an imperfection in the bird, inasmuch as wings, composed of these feathers, although they may greatly assist it in running, do not serve for flight.

But under the present division of our subject, our business with feathers is, as they are the *covering* of the bird. And herein a singular circumstance occurs. In the small order of birds which winter with us, from a snipe downwards, let the external colour of the feathers be what it will, their Creator has universally given them a bed of *black* down next their bodies. Black, we know, is the warmest colour; and the purpose here is, to *keep in* the heat, arising from the heart and circulation of the blood. It is farther likewise remarkable, that this is not found in larger birds; for which there is also a reason:—small birds are much more exposed to the cold than large ones; forasmuch as they present, in proportion to their bulk, a much larger surface to the air. If a turkey were divided

* The above account is taken from Memoirs for a Natural History of Animals, by the Royal Academy of Paris, published in 1701, p. 209.

into a number of wrens, (supposing the shape of the turkey and the wren to be similar,) the surface of all the wrens would exceed the surface of the turkey, in the proportion of the length, breadth (or, of any homologous line,) of a turkey to that of a wren; which would be, perhaps, a proportion of ten to one. It was necessary, therefore, that small birds should be more warmly clad than large ones: and this seems to be the expedient by which that exigency is provided for.

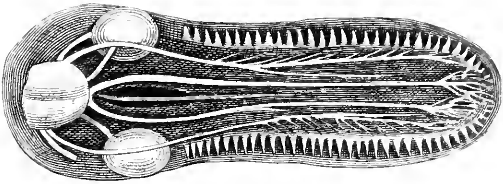
II. In comparing different animals, I know no part of their structure which exhibits greater variety, or, in that variety, a nicer accommodation to their respective conveniency, than that which is seen in the different formations of their *mouths*. Whether the purpose be the reception of aliment merely, or the catching of prey, the picking up of seeds, the cropping of herbage, the extraction of juices, the suction of liquids, the breaking and grinding of food, the taste of that food, together with the respiration of air, and, in conjunction with it, the utterance of sound; these various offices are assigned to this one part, and, in different species, provided for, as they are wanted, by its different constitution. In the human species, forasmuch as there are hands to convey the food to the mouth, the mouth is flat, and by reason of its flatness, fitted only for *reception;* whereas the projecting jaws, the wide rictus, the pointed teeth of the dog and his affinities, enable them to apply their mouths to *snatch and seize* the objects of their pursuit. The full lips, the rough tongue, the corrugated cartilaginous palate, the broad cutting teeth of the ox, the deer, the horse, and the sheep, qualify this tribe for *browsing* upon their pasture; either gathering large mouthfuls at once, where the grass is long, which is the case with the ox in particular; or biting close, where it is short, which the horse and the sheep are able to do, in a degree that one could hardly expect. The retired under-jaw of a swine *works in the ground*, after the protruding snout, like a prong or ploughshare, has made its way to the roots upon which it feeds. A conformation so happy was not the gift of chance.

In *birds*, this organ assumes a new character; new both in substance and in form; but in both, wonderfully adapted to the wants and uses of a distinct mode of existence. We have no longer the fleshy lips, the teeth of enamelled bone; but we have, in the place of these two parts, and to perform the office of both, a hard substance (of the same nature with that which composes the nails, claws, and hoofs of quadrupeds) cut out into proper shapes, and mechanically suited to the actions which are wanted. The sharp edge and tempered point of the *sparrow's* bill picks almost every kind of seed from its concealment in the plant; and not only so, but hulls the grain, breaks and shatters the coats of the seed, in order to get at the kernel. The hooked beak of the hawk tribe separates the flesh from the bones of the animals which it feeds upon, almost with the cleanness and precision of a dissector's knife. The butcher-bird transfixes its prey upon the spike of a thorn, whilst it picks its bones. In some birds of this class, we have the *cross*-bill, *i. e.* both the upper and lower bill hooked, and their tips crossing. The *spoon*-bill enables the goose to graze, to collect its food from the bottom of pools, or to seek it amidst the soft or liquid substances with which it is mixed. The *long* tapering bill of the snipe and woodcock, penetrates still deeper into moist earth, which is the bed in which the food of that species is lodged. This is exactly the instrument which the animal wanted. It did not want strength in its bill, which was inconsistent with the slender form of the animal's neck, as well as unnecessary for the kind of aliment upon which it subsists; but it wanted length to reach its object.

But the species of bill which belongs to birds that live by *suction*, deserves to be described in its relation to that office. They are what naturalists call serrated or dentated bills; the inside of them, towards the edge, being thickly set with parallel or concentric rows of short, strong, sharp-pointed prickles. These, though they should be called teeth, are not for the purpose of mastication, like the teeth of quadrupeds; nor yet, as in fish, for the seizing and retaining of their prey; but for a quite different use. They form a filter. The *duck* by means of them discusses the mud; examining with great accuracy the puddle, the brake, every mixture which is likely to contain her food. The operation is thus carried on:—The liquid or semiliquid substances, in which the animal has plunged her bill, she draws, by the action of her lungs, through the narrow interstices which lie between these teeth; catching, as the stream passes across her beak, whatever it may happen to bring along with it, that proves agreeable to her choice, and easily dismissing all the rest. Now, suppose the purpose to have been, out of a mass of confused heterogeneous substances, to separate for the use of the animal, or rather to enable the animal to separate for its own, those few particles which suited its taste and digestion; what more artificial, or more commodious instrument of selection, could have been given to it, than this natural filter?* It has been observed, also, (what must enable the bird to choose and distinguish with greater acuteness, as well, probably, as what greatly increases its luxury,) that the bills of this species are furnished with large nerves, that they are covered with a skin,—and that the nerves run down to the very extremity. In the curlew,

* There is a remarkable contrivance of this kind in the genus *balæna*, or proper whale. Numerous parallel plates of the substance called whalebone, cover the palatine surface of the upper jaw, and descend vertically into the mouth; the lower edges are fringed by long fibres, which serve the animal, when taking in the water, to retain the mollusceæ, with which the water abounds, and which constitute its food.

TAB. XXIII



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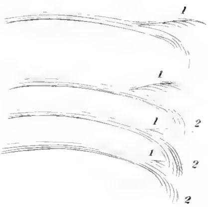

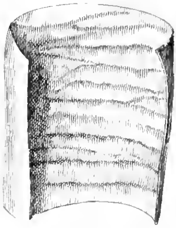

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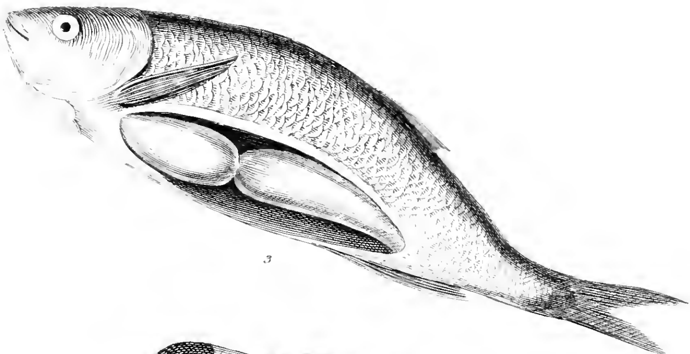

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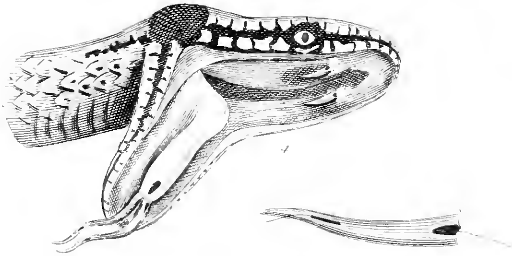

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woodcock, and snipe, there are *three pairs* of nerves, equal almost to the optic nerve in thickness, which pass first along the roof of the mouth, and then along the upper chap down to the point of the bill, long as the bill is.*

But to return to the train of our observations. —The similitude between the bills of birds and the mouths of quadrupeds, is exactly such as, for the sake of the argument, might be wished for. It is near enough to show the continuation of the same plan; it is remote enough to exclude the supposition of the difference being produced by action or use. A more prominent contour, or a wider gap, might be resolved into the effect of continued efforts, on the part of the species, to thrust out the mouth, or open it to the stretch. But by what course of action, or exercise, or endeavour, shall we get rid of the lips, the gums, the teeth; and acquire, in the place of them, pincers of horn? By what habit shall we so completely change, not only the shape of the part, but the substance of which it is composed? The truth is, if we had seen no other than the mouths of quad-

* Tab. XXIII. Fig. 1. the upper *mandible* of the duck, on which are distributed the first and second branches of the fifth pair of nerves; the former passing through the orbit to the extremity of the bill, and, together with the latter, supplying the whole palatine surface. This gustatory sensibility is the more necessary to those races of birds called palmipedes, such as penguins, the wild goose, ducks, &c. and the grallæ, such as water-hens, curlews, woodcocks, &c. their sight being of no assistance to them in finding their prey in the mire.

rupeds, we should have thought no other could have been formed: little could we have supposed, that all the purposes of a mouth furnished with lips, and armed with teeth, could be answered by an instrument which had none of these; could be supplied, and that with many additional advantages, by the hardness, and sharpness, and figure of the bills of birds. Every thing about the animal *mouth* is mechanical. The teeth of fish have their points turned backward, like the teeth of a wool or cotton card. The teeth of lobsters work one against another, like the sides of a pair of shears. In many insects, the mouth is converted into a pump or sucker, fitted at the end sometimes with a wimble, sometimes with a forceps; by which double provisions, viz. of the tube and the penetrating form of the point, the insect first bores through the integuments of its prey, and then extracts the juices. And, what is most extraordinary of all, one sort of mouth, as the occasion requires, shall be changed into another sort. The caterpillar could not live without teeth; in several species, the butterfly formed from it could not use them. The old teeth therefore are cast off with the exuviæ of the grub; a new and totally different apparatus assumes their place in the fly. Amid these novelties of form, we sometimes forget that it is, all the while, the animal's *mouth;* that, whether it be lips, or teeth, or bill, or beak, or shears, or pump, it is the same part diversified:

and it is also remarkable, that, under all the varieties of configuration with which we are acquainted, and which are very great, the organs of taste and smelling are situated near each other.

III. To the mouth adjoins the gullet: in this part also, comparative anatomy discovers a difference of structure, adapted to the different necessities of the animal. In brutes, because the posture of their neck conduces little to the passage of the aliment, the fibres of the gullet, which act in this business, run in two close spiral lines, crossing each other: in men these fibres run only a little obliquely from the upper end of the œsophagus to the stomach, into which, by a gentle contraction, they easily transmit the descending morsels; that is to say, for the more laborious deglutition of animals, which thrust their food *up* instead of *down*, and also through a longer passage, a proportionably more powerful apparatus of muscles is provided; more powerful, not merely by the strength of the fibres, which might be attributed to the greater exercise of their force, but in their collocation, which is a determinate circumstance, and must have been original.

IV. The gullet leads to the *intestines;* here, likewise, as before, comparing quadrupeds with man, under a general similitude we meet with appropriate differences. The *valvulæ conniventes*, or, as they are by some called, the semilunar valves, found in the human intestine, are wanting in that of brutes. These are wrinkles or plaits of the innermost coat of the guts, the effect of which is, to retard the progress of the food through the alimentary canal. It is easy to understand how much more necessary such a provision may be to the body of an animal of an erect posture, and in which, consequently, the weight of the food is added to the action of the intestine, than in that of a quadruped, in which the course of the food, from its entrance to its exit, is nearly horizontal: but it is impossible to assign any cause, except the final cause, for this distinction actually taking place.* So far as depends upon the action of the part, this structure was more to be expected in a quadruped than in a man. In truth, it must in both have been formed, not by action, but in direct opposition to action and to pressure; but the opposition which would arise from pressure, is greater in the upright trunk than in any other. That theory therefore is pointedly contradicted by the example before us. The structure is found where its generation, according to the method by

* Fig. 2. The intestine cut open in order to shew the valvulæ. It may be questioned, whether these extremely soft rugæ or folds of the villous coat of the intestine can in the least retard the passage of the food through its canal; nor does the erect attitude of man require them; for, since there are as many of the convolutions of the intestines ascending as there are descending, the weight of the food can have no influence in the action of the intestine: it is certain, however, that this arrangement of the internal coat, affords *a more extensive surface for the lacteals and secreting vessels;* and this appears to be the real use of the *valvulæ conniventes.*

which the theorist would have it generated, is the most difficult; but (*observe*) it is found where its effect is most useful.

The different length of the intestines in carnivorous and herbivorous animals, has been noticed on a former occasion. The shortest, I believe, is that of some birds of prey, in which the intestinal canal is little more than a straight passage from the mouth to the vent. The longest is in the deer-kind. The intestines of a Canadian stag, four feet high, measured ninety-six feet.* The intestine of a sheep, unravelled, measured thirty times the length of the body. The intestine of a wild cat is only three times the length of the body. Universally, where the substance upon which the animal feeds is of slow concoction, or yields its chyle with more difficulty, there the passage is circuitous and dilatory, that time and space may be allowed for the change and the absorption which are necessary. Where the food is soon dissolved, or already half assimilated, an unnecessary, or perhaps hurtful, detention is avoided, by giving to it a shorter and a readier route.†

V. In comparing the *bones* of different animals, we are struck, in the bones of birds, with a *pro-*

* Mem. Acad. Paris. 1701, p. 170.

† The whole length of the alimentary canal is greater in the mammalia than in other classes. It diminishes successively as we trace it in birds, reptiles, and fishes, being shorter than the body in some of the latter animals, which is never the case in the three first classes.

priety, which could only proceed from the wisdom of an intelligent and designing Creator. In the bones of an animal which is to fly, the two qualities required are strength and lightness. Wherein, therefore, do the bones of birds (I speak of the cylindrical bones) differ in these respects from the bones of quadrupeds? In three properties: first, their cavities are much larger in proportion to the weight of the bone than in those of quadrupeds; secondly, these cavities are empty; thirdly, the shell is of a firmer texture than the substance of other bones. It is easy to observe these particulars, even in picking the wing or leg of a chicken. Now, the weight being the same, the diameter, it is evident, will be greater in a hollow bone than in a solid one, and with the diameter, as every mathematician can prove, is increased, *cæteris paribus*, the strength of the cylinder, or its resistance to breaking. In a word, a bone of the *same weight* would not have been so strong in any other form; and to have made it heavier, would have incommoded the animal's flight.* Yet this form could not be acquired by use, or the bone become hollow

* The bones of birds admit air into their cavities, not only in those species which fly, but also in those which swim, or run with rapidity; *e. g.* the ostrich, cassowary, the great hawk, &c.: hence there does not appear to be any reason for doubting, that one at least among the objects of this provision is to favour the motion of this class of animals in the air or water, by giving them a greater degree of buoyancy by the diminution of the relative weight resulting from the increase of surface.

and tubular by exercise. What appetency could excavate a bone?

VI. The *lungs* also of birds, as compared with the lungs of quadrupeds, contain in them a provision, distinguishingly calculated for this same purpose of levitation; namely, a communication (not found in other kinds of animals) between the air-vessels of the lungs and the cavities of the body; so that by the intromission of air from one to the other (at the will, as it should seem, of the animal,) its body can be occasionally puffed out, and its tendency to descend in the air, or its specific gravity, made less. The bodies of birds are blown up from their lungs (which no other animal bodies are,) and thus rendered buoyant.*

VII. All birds are *oviparous*. This likewise carries on the work of gestation with as little increase as possible of the weight of the body. A gravid uterus would have been a troublesome burden to a bird in its flight. The advantage, in this respect, of an oviparous procreation is, that whilst the whole brood are hatched together, the eggs are excluded singly, and at considerable in-

* The organs of respiration in birds are especially singular from their connexion with numerous air cells, extended generally over the whole body, but particularly in the abdomen; a great part of which is occupied by membranous cells which open by considerable apertures into the lungs; a considerable part also of the bones are destitute of marrow and become receptacles for air; the largest and most numerous bony cells being found in birds which have the highest and most rapid flight. The barrels of the quills, and even the softer parts, in some species, have cavities which are inflated.

tervals. Ten, fifteen, or twenty young birds may be produced in one cletch or covey, yet the parent bird have never been encumbered by the load of more than one full-grown egg at one time.

VIII. A principal topic of comparison between animals, is in their *instruments of motion*. These come before us under three divisions; feet, wings, and fins. I desire any man to say, which of the three is best fitted for its use; or whether the same consummate art be not conspicuous in them all. The constitution of the elements in which the motion is to be performed, is very different. The animal action must necessarily follow that constitution. The Creator, therefore, if we might so speak, had to prepare for different situations, for different difficulties; yet the purpose is accomplished not less successfully in one case than in the other; and, as between *wings* and the corresponding limbs of quadrupeds, it is accomplished without deserting the general idea. The idea is modified, not deserted. Strip a wing of its feathers, and it bears no obscure resemblance to the fore-leg of a quadruped. The articulations at the shoulder and the cubitus are much alike; and, what is a closer circumstance, in both cases the upper part of the limb consists of a single bone, the lower part of two.

But, fitted up with its furniture of feathers and quills, it becomes a wonderful instrument, more artificial than its first appearance indicates, though that be very striking: at least, the use which the bird makes of its wings in flying is more complicated, and more curious, than is generally known. One thing is certain, that if the flapping of the wings in flight were no more than the reciprocal motion of the same surface in opposite directions, either upwards and downwards, or estimated in any oblique line, the bird would lose as much by one motion as she gained by another. The sky-lark could never ascend by such an action as this; for, though the stroke upon the air by the under side of her wing would carry her up, the stroke from the upper side, when she raised her wing again, would bring her down. In order, therefore, to account for the advantage which the bird derives from her wing, it is necessary to suppose that the surface of the wing, measured upon the same plane, is contracted whilst the wing is drawn up; and let out to its full expansion, when it descends upon the air for the purpose of moving the body by the re-action of that element. Now, the form and structure of the wing, its external convexity, the disposition, and particularly the overlapping, of its larger feathers, the action of the muscles,* and joints of the pinions, are all adapted to this alternate adjustment of its shape

* There are three powerful muscles (the fleshy part of the breast) called pectoral muscles, which, with other smaller on the bones of the wing which are analogous to the arm, press with vigour on the air, the elasticity of which gives support. "And it is remarkable that the general resemblance which the best form of windmill sails bear to the feathers of the wings of birds is striking, and one of those beautiful instances of truly mathematical principles on which the works of creation are constructed."

and dimensions. Such a twist, for instance, or semirotatory motion, is given to the great feathers of the wing, that they strike the air with their flat side, but rise from the stroke slantwise. The turning of the oar in rowing whilst the rower advances his hand for a new stroke, is a similar operation to that of the feather, and takes its name from the resemblance. I believe that this faculty is not found in the great feathers of the tail. This is the place also for observing, that the pinions are so set upon the body as to bring down the wings, not vertically, but in a direction obliquely tending towards the tail; which motion, by virtue of the common resolution of forces, does two things at the same time; supports the body in the air, and carries it forward. The *steerage* of a bird in its flight is effected partly by the wings, but in a principal degree by the tail. And herein we meet with a circumstance not a little remarkable. Birds with long legs have short tails, and in their flight place their legs close to their bodies, at the same time stretching them out backwards as far as they can. In this position, the legs extend beyond the rump, and become the rudder, supplying that steerage which the tail could not.

From the *wings* of birds, the transition is easy to the *fins* of fishes. They are both, to their respective tribes, the instruments of their motion; but, in the work which they have to do, there is a considerable difference, founded in this circumstance.

Fish, unlike birds, have very nearly the same specific gravity with the element in which they move. In the case of fish, therefore, there is little or no weight to bear up; what is wanted, is only an impulse sufficient to carry the body through a resisting medium, or to maintain the posture, or to support or restore the balance of the body, which is always the most unsteady where there is no weight to sink it. For these offices the fins are as large as necessary, though much smaller than wings, their action mechanical, their position, and the muscles by which they are moved, in the highest degree convenient. The following short account of some experiments upon fish, made for the purpose of ascertaining the use of their fins, will be the best conformation of what we assert. In most fish, besides the great fin, the tail, we find two pair of fins upon the sides, two single fins upon the back, and one upon the belly, or or rather between the belly and the tail. The *balancing* use of these organs is proved in this manner. Of the large-headed fish, if you cut off the pectoral fins, *i. e.* the pair which lies close behind the gills, the head falls prone to the bottom; if the right pectoral fin only be cut off, the fish leans to that side; if the ventral fin on the same side be cut away, then it loses its equilibrium entirely; if the dorsal and ventral fins be cut off, the fish reels to the right and left. When the fish dies, that is, when the fins cease to play, the belly turns upwards. The use of the same parts for *motion* is seen in the following observation upon them when put in action. The pectoral, and particularly the ventral fins, serve to *raise and depress* the fish: when the fish desires to have a *retrograde* motion, a stroke forward with the pectoral fin effectually produces it; if the fish desire to *turn* either way, a single blow with the tail the opposite way, sends it round at once: if the tail strike both ways, the motion produced by the double lash is *progressive*, and enables the fish to dart forwards with an astonishing velocity. The result is not only in some cases the most rapid, but in all cases the most gentle, pliant, easy animal motion with which we are acquainted. However, when the tail is cut off, the fish loses all motion, and gives itself up to where the water impels it. The rest of the fins, therefore, so far as respects motion, seem to be merely subsidiary to this. In their mechanical use, the anal fin may be reckoned the keel; the ventral fins, out-riggers; the pectoral muscles, the oars:* and if there be any simi-

* The pectoral *fins* are the *oars*, the muscles are, in all cases, the prime movers in animal strength; and if we are allowed to carry on the comparison, the pectoral *muscles* of the fish are the *rowers*. In other words the fins, which in fish supply the place of external extremities, may be considered as hands for swimming, provided with numerous delicate fingers, articulated, and connected together by a web. From the point to which they are attached they receive the name of dorsal, caudal, pectoral, ventral and anal fins, the pectoral and ventral correspond to the anterior and posterior extremities.

litude between these parts of a boat and a fish, observe, that it is not the resemblance of imitation, but the likeness which arises from applying similar mechanical means to the same purpose.

We have seen that the *tail* in the fish is the great instrument of motion. Now, in cetaceous or warm-blooded fish, which are obliged to rise every two or three minutes to the surface to take breath, the tail, unlike what is in other fish, is horizontal; its stroke consequently perpendicular to the horison, which is the right direction for sending the fish to the top, or carrying it down to the bottom.

Regarding animals in their instruments of motion we have only followed the comparison through the first great division of animals into beasts, birds, and fish. If it were our intention to pursue the consideration farther, I should take in that generic distinction amongst birds, the *web-foot* of water-fowl. It is an instance which may be pointed out to a child. The utility of the web to water-fowl, the inutility to land-fowl, are so obvious, that it seems impossible to notice the difference without acknowledging the design. I am at a loss to know, how those who deny the agency of an intelligent Creator dispose of this example. There is nothing in the action of swimming, as carried on by a bird upon the surface of the water, that should generate a membrane between the toes. As to that membrane, it is an exercise of constant resistance. The only supposition I can think of is, that all birds have been originally water-fowl, and web-footed; that sparrows, hawks, linnets, &c. which frequent the land, have, in process of time, and in the course of many generations, had this part worn away by treading upon hard ground. To such evasive assumptions must atheism always have recourse! and, after all, it confesses that the structure of the feet of birds, in their original form, was critically adapted to their original destination! The web-feet of amphibious quadrupeds, seals, otters, &c. fall under the same observation.

IX. The *five senses* are common to most large animals: nor have we much difference to remark in their constitution; or much, however, which is referable to mechanism.

The superior sagacity of animals which hunt their prey, and which consequently, depend for their livelihood upon their *nose*, is well known in its use; but not at all known in the organization which produces it.*

The external *ears* of beasts of prey, of lions, tigers, wolves, have their trumpet part, or concavity, standing forwards, to seize the sounds which are before them, viz. the sounds of the animals which they pursue or watch. The ears of animals of flight are turned backward, to give notice of

* From observation we know that the olfactory nerves of such animals are exceedingly large and extended.

the approach of their enemy from behind, whence he may steal upon them unseen. This is a critical distinction; and is mechanical: but it may be suggested, and I think not without probability, that it is the effect of continual habit.*

The *eyes* of animals which follow their prey by night, as cats, owls, &c. possess a faculty not given to those of other species, namely, of closing the pupil *entirely*. The final cause of which seems to be this: it was necessary for such animals to be able to descry objects with very small degrees of light. This capacity depended upon the superior sensibility of the retina; that is, upon its being affected by the most feeble impulses. But that tenderness of structure, which rendered the membrane thus exquisitely sensible, rendered it also liable to be offended by the access of stronger degrees of light. The contractile range, therefore, of the pupil is increased in these animals, so as to enable them to close the aperture entirely: which includes the power of diminishing it in every degree; whereby at all times such portions, and only such portions of light are admitted, as may be received without injury to the sense.

There appears to be also in the figure, and in

* There is a deficiency of the external ear in some instances, as in the cetacea, several seals, and the walrus, ornithorinchi, moles, and shrews; and we easily conceive that, from their habits, these animals scarcely need them. In other species the ear attains an extraordinary size, particularly in the long-eared bat.

some properties of the pupil of the eye, an appropriate relation to the wants of different animals. In horses, oxen, goats, sheep, the pupil of the eye is elliptical; the transverse axis being horizontal; by which structure, although the eye be placed on the side of the head, the anterior elongation of the pupil catches the forward rays, or those which come from objects immediately in front of the animal's face.

END OF VOL. I.

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