PALEY, William

PALEY'S NATURAL THEOLOGY;

WITH

ILLUSTRATIVE NOTES,

BY

HENRY, LORD BROUGHAM, F.R.S., AND SIR C. BELL, K.G.H., &c.

AND AN INTRODUCTORY

DISCOURSE OF NATURAL THEOLOGY,

BY LORD BROUGHAM:

TO WHICH ARE ADDED,

SUPPLEMENTARY DISSERTATIONS,

AND A TREATISE ON ANIMAL MECHANICS,

BY SIR CHARLES BELL.

WITH NUMEROUS WOODCUTS.

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ILLUSTRATIVE WOODCUTS.—VOL. II.

NATURAL THEOLOGY.

CHAPTER I.

STATE OF THE ARGUMENT.[1]

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 anything 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.[2] But suppose I had found a *watch* upon the ground, and it should be inquired how the watch hap-

[1] The last note of the Appendix describes the mechanism of a watch, and illustrates the elementary principles of mechanics. Contrasted with the mere mechanism, there is another essay on the mechanism of the animal body. These may be perused either before or after reading the present chapter.

[2] The argument is here put very naturally. But a considerable change has taken place of late years in the knowledge attained even by common readers, and there are few who would be without reflection "how the stone came to be there." The changes which the earth's surface has undergone, and the preparation for its present condition, have become a subject of high interest; and there is hardly any one who now would, for an instant, believe that the stone was formed where it lay. On lifting it, he would find it rounded like gravel in a river: he would see that its asperities had been worn off, by being rolled from a distance in water: he would perhaps break it, look to its fracture, and survey the surrounding heights, to discover whence it had been broken off, or from what remote region it had been swept hither: he would consider the place where he stood,

pened 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

in reference to the level of the sea or the waters; and, revolving all these things in his mind, he would be impressed with the conviction that the surface of the earth had undergone some vast revolution.

Such natural reflections lead an intelligent person to seek for information in the many beautiful and interesting works on geology that have been published in our country of late years. And by these he will be led to infer that the fair scene before him, so happily adapted for the abode of man, was a condition of the earth resulting from many successive revolutions taking place at periods incalculably remote; and that the variety of mountain and valley, forest and fertile plain, promontory and shallow estuary, formed a world suited to his capacities and enterprise.

So true is the observation of Sir J. Herschel, "that the situation of a pebble may afford him evidence of the state of the globe he inhabits myriads of ages ago, before his species became its denizens."

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 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, 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?[3] Ignorance

[3] It is certainly a thing not easily expressed in words. The nave of a circular wheel moves on a single pivot; but there are here two pivots, and grooves in the wheel to corre-

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 show 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 ques-

spond with them. These two grooves cross each other, and play upon the pivots in such a manner that the centre of motion varies, and the rim of the wheel moves in an ellipsis. It is exactly on the same principle that we draw an oval figure, by driving two nails into a board, and throwing a band round them, and then running the pencil round within the band. These two nails are in the points called by mathematicians the *foci* of the oval or ellipse; and accordingly a fundamental property of the curve is, that the sum of any two lines whatever, drawn from the two *foci* to any point in the curve, is always the same. These points are called *foci*, *fires*, because light reflected from the surface of an oval mirror is concentrated there and produces heat.

tion, 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 inquiry 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 anything. A law presupposes 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.[4]

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.

[4] When philosophers and naturalists observe a certain succession in the phenomena of the universe, they consider the uniformity to exist through a *law of nature*. If they discover the order of events, or phenomena, they say they have discovered the law: for example, the law of affinities, of gravitation, &c. It is a loose expression; for to obey a law supposes an understanding and a will to comply. The phrase also implies that we know the nature of the governing power which is in operation, and in the present case both conditions are wanting.

The "law" is the mode in which the power acts, and the term should infer, not only an acquiescence in the existence of the power, but of Him who has bestowed the power and enforced the law.

The term "force" is generally used instead of power, when the intensities are measurable in their mechanical results.

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 lathes, 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 anywise 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 anything 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 anything 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; the contrivance must have had a contriver. That former one from one preceding 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 unorganised, unmechanised 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 unorganised 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 adapted 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 for 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.

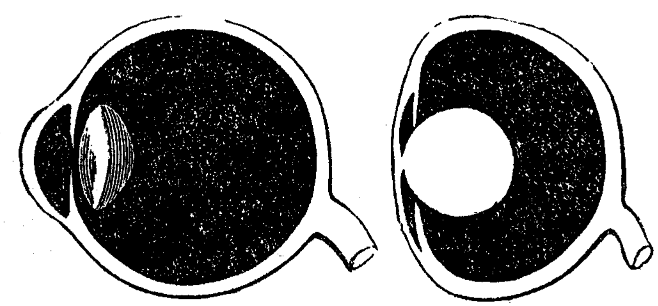
The conclusion which the *first* examination of the watch, of its works, construction, and movement, suggested, was, that it must have had, for the cause and author of that construction, an artificer who understood its mechanism and designed its use. This conclusion is invincible. A *second* examination 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 organisation, 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.[5]

[5] We must leave this logical and satisfactory argument untouched. In this chapter our author is laying the foundation for a course of reasoning on the mechanism displayed in the animal body. The argument in favour of a creating and presiding Intelligence may be drawn from the study of the laws of physical agency:—such as the properties of heat, light, and sound; of gravitation, and chemical combination; the structure of the globe, the divisions of land and sea, the distribution of temperature; nay, the mind may rise to the contemplation of the sun and planets, their mutual dependence, and their revolutions; but, as affording proofs obvious not only to cultivated reason but to plain sense, almost to ignorance, there is nothing to be compared with that for which our author is preparing the reader in this chapter, the mechanism of the animal body, and the adaptations which affect the well-being of living creatures.

CHAPTER III.

APPLICATION OF THE ARGUMENT.[6]

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 and 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.



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

[6] The arguments adduced in this chapter being drawn from the laws according to which light is refracted by the humours of the eye, the reader may be inclined to peruse the few observations on the elements of this part of physics in the Appendix, No. 16.

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 show 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?[7]

[7] The reader will find a comparison, more in detail, between the eye and optical instruments, in the Appendix, No. 17.

In illustration of the instance adduced here, of the adaptation of the fish's eye to the medium in which it lives, we may observe that the powers in the human eye, for example, of drawing the pencil of rays to a focus, and producing an accurate image upon the expanded optic nerve (called the retina, from its net-work structure) in the bottom of the eye, depends principally upon two circumstances,—the form of the cornea and the convexity of the lens. That the cornea may produce this effect, it is not only necessary that it should be convex (as in the left-hand figure on page 17), but that the rays should enter it from a rarer medium. As this cannot be effected in the water, the lens or crystalline humour, which is much denser than water, is brought into operation. In the eye of an animal living in the atmosphere,

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 something 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 being 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

the lens is removed backwards, and resembles the optician's double convex lens; but in the fish it is a sphere, and being brought in contact with the transparent cornea, it not only has the power to concentrate the rays of light coming through the water, but by its altered position it increases greatly the sphere of vision. (See the right-hand figure, page 17.) To be critically correct, we may add that it is not exactly the cornea which is deficient in the fish, but the aqueous humour behind it. An aqueous fluid being thus both behind and before the cornea, and that membrane being in a very slight degree thicker in the centre than in the margin, this part of the organ which is so efficient in the atmosphere is rendered useless in water. A man diving, for example, sees imperfectly, being in something worse than the condition of an old man who requires spectacles.

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 shown. 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 accomplishing that purpose is in both alike. The lenses of the telescope, and the humours of the eye, bear a complete 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: namely, 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?

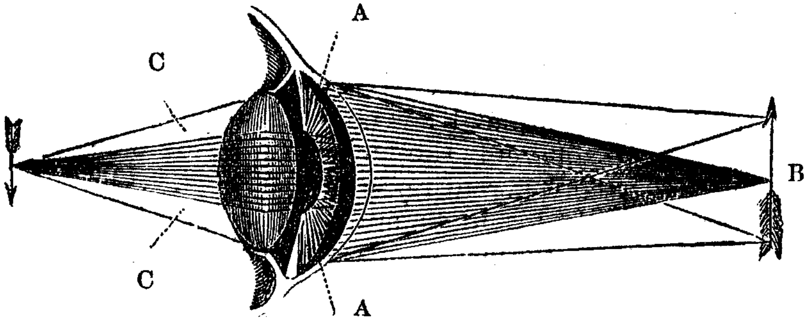
The resemblance between the two cases is still more accurate, and obtains in more points than we have yet represented, or than we are, on the first view of the subject, aware of. In dioptric telescopes there is an imperfection of this nature. Pencils of light, in passing through glass lenses, are separated into different colours, thereby tinging the 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 exactly 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?[8]

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

[8] This is an interesting part of the inquiry, which will be found more fully explained in the Appendix.

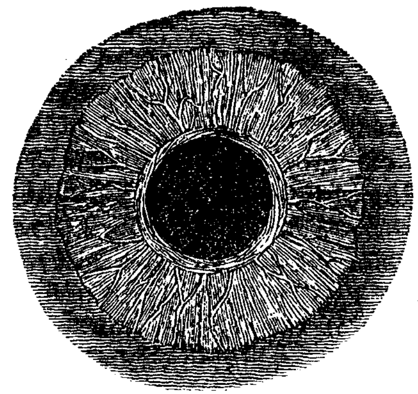
It is not, accurately speaking, "glasses of different refracting powers" which are required. Refraction is the new direction which the ray takes in passing from one transparent body into another of different density. Dispersion is the separation of the beam of light into differently coloured rays. A piece of glass may differ from another in its power of refracting, and also in its property of dispersing. It is by duly arranging these different properties that the achromatic telescope is formed.



[This figure represents a section of the anterior part of the human eye :—A, A, the iris ; B, the object, from which the rays strike off in all directions : a pencil of these enters at the pupil ; a portion is intercepted by the iris A, A. The pencil which enters the eye, passing through the lens, converges to form the image. But the spaces C, C, are deprived of rays by the intervention of the iris A, A. Yet this in no measure affects the size of the image, but only diminishes the intensity of its illumination. By the contraction of the iris, and consequent enlargement of the pupil, a larger pencil of rays is admitted. It is remarkable that the image formed on the retina must always be inverted, and yet such is the power of habit and experience, derived from touching objects, that we see things as they are in reality, and not as they are painted in our eyes—experience thus correcting the errors of sense. It is in the same way that we see single, though we have an image made in each eye. But if we change the ordinary position of our eye, the habit is broken, and we see double.]

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 lesser 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 opening ; when too strong, can again contract it ; and that without any other assistance than that of its own exquisite machinery. It is farther 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 shall 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.



[This figure represents the iris separated from the eye and laid out flat. We perceive the straight fibres passing towards the inner margin, and the circular fibres running round the margin.]

II. The second difficulty which has been stated 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 remaining 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 this 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 muscles, 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 anything 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 the same time drawing out also his tube to a different length.[9]

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

[9] This is a subject over which there is still great obscurity, and on which adverse experiments and opinions are recorded. However difficult it may be to account for the mode of adjustment, yet the property is not denied, and therefore the argument in the text remains. That there is something in the sensibility of the nerve, and in the power of attention, there seems no doubt. Birds of prey, it has been noticed, possess a power of vision of which we can hardly form a conception. Where it is the object to snare the falcon, a pigeon is tied, in an exposed situation, with a cord so attached that a person concealed can flutter the bird, or make it extend its wings; and although no bird of prey be visible in the whole sky, presently the hawk will be seen descending to pounce upon the pigeon. The endowment of the bird's eye must be different from ours, else the bird of prey could not see the most minute object when hovering at a great height; nor, in sweeping down upon his quarry, could he strike it with precision. Nothing of the nature of mere mechanical provision can account for the possession of this superior power. One instance of the power of adjustment which the eye has under the influence of the will, seems to be this. Let a person who cannot read distinctly, or at all, without spectacles, at a given distance, look at a word through a very small aperture, and he will see what he before could not without spectacles. This can hardly be explained by the removal of the lateral light, or by inflection.

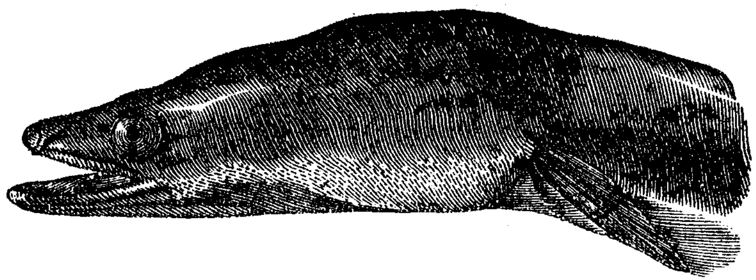
refraction; composed of parts executing different offices: one part having fulfilled its office upon the pencil of light, delivering it over to the action of another part; that to a third, and so onward: the progressive action depending for its success upon the nicest and minutest adjustment of the parts 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, living in the 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 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 fish, 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 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 fish 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 anything 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.[10]

[10] In viewing the structure of the eye as adjusted to the condition of fishes, we may remark the peculiar thickness of the sclerotic coat in the whale. Although he breathes the atmosphere, and lies out on the surface of the water, to escape his enemies he will plunge some hundred fathoms deep. The pressure therefore must be very great upon his surface, and on the surface of the eye. If a cork be knocked into the mouth of a bottle, so that it resists all further pressure that we can make upon it, and if this bottle be carried, by being attached to the sounding-lead, to a great depth in the sea, the pressure of the water will force in the cork, and fill the bottle; for the cork is pressed with a force equal to the weight of the column of water above it, of which it is the base. It is pressed in all directions equally, so that a common-sized cork is reduced to the size of that of a phial bottle.

"A creature living at the depth of 100 feet would sustain a pressure, including that of the atmosphere, of about 60

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 axis of the eye meets the retina,

pounds on the square inch; while one at 4000 feet, a depth by no means considerable, would be exposed to a pressure of about 1830 pounds upon the square inch."—*De la Beche, Theor. Geol.*, p. 243.

We can therefore comprehend how it shall happen, that on the foundering of a ship at sea, though its timbers part, not a spar floats to the surface; everything is swallowed up; for, if the hull has sunk to a great depth, all that is porous is penetrated with water, or compressed, and consequently remains where it sunk. So it happened, and the fact goes directly to our purpose, that when, by the entangling of the line of the harpoon, the boat was carried down with the whale, and, being recovered, it required two boats to keep it at the surface.—*Scoresby*.

We may easily conceive, therefore, the pressure which the eye of the whale sustains when it dives, and why it is formed with the provisions which we are about to describe. When we make a section of the whole eye, cutting through the cornea, the sclerotic coat, which is dense as tanned leather, increases in thickness towards the back part, and is full five times the thickness behind, that it is at the anterior part. The anterior part of the eye sustains the pressure from without, and requires no additional support; but were the back part to yield, the globe would be then distended in that direction, and the whole interior of the eye consequently suffer derangement. We perceive, therefore, the necessity of the coats being thus so remarkably strengthened behind. The natural enemies of the whale are the sword-fish and the shark; and it is stated with some show of reason, that this huge creature, being without means of defence of any kind, carries his enemies that have fixed upon him to a depth of water, and consequently to a pressure, which subdues them, as their bodies are not constituted for such depths. It is under this instinct, that when the whale receives the harpoon, he dives to the bottom.

* The eye of the seal or sea-calf, I understand, is an exception. Mem. Acad. Paris, 1710, p. 123.—*Paley*.

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 an 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 anything 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.

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 everything 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 edges. 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 shows the same care. Within this socket it is embedded in fat, of all animal substances the best adapted both to its repose and motion. It is sheltered by the eyebrows—an arch of hair, which, like a thatched penthouse, prevents the sweat and moisture of the forehead from running down into it.

* Heister, sect. 89.

† Mem. R. Acad. Paris, p. 117.—*Paley.*

But it is still better protected by its *lid*. Of 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 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 fish—the element in which they live supplying a constant lotion to the eye.[11]

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, 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 upper 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 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

[11] We have entered into a much fuller explanation of the apparatus for the preservation of the eye, in the Appendix, there being a great deal that is curious in it hitherto unnoticed. It will be there found that, although the eye of the fish has no eyelid, yet it has the rapid motion of the eyeball, which, under water, must serve to free it from any impurity. Some curious instances are, at the same time, afforded, of a still more artificial mode, in the lobster and crab, of removing whatever obstructs the sight.

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 anything 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 their 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." †

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.

* 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, p. 249.—*Paley*.

This so far answers the end; but, still farther, 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.[12]

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

[12] There is one effect, however, of this apparatus, which our author has omitted to notice—that is, the rapidity of motion in the *membrana nictitans,* produced by the oblique direction and junction of the tendons of these muscles. This will be illustrated hereafter.

The *membrana nictitans* is peculiar to birds: the term is not applicable to the corresponding structure in quadrupeds, the object being there obtained by a very different mechanism. The *haw* is a thin cartilage, which, lying between the eye-ball and the inner part of the orbit, flies rapidly out, and sweeps the surface of the eye in a manner much more perfect than can be performed by the outer eyelids. Every one who has ridden a horse in a dusty road must have been struck with the superior provision in the horse's eye: he never suffers from the dust, because, this cartilage, being bedewed by the secretion of a peculiar gland, not tears, but a matter more glutinous, sweeps across the eye, and collects and removes every particle of dust.

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 reasons 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 phenomena, 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 prescribed 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

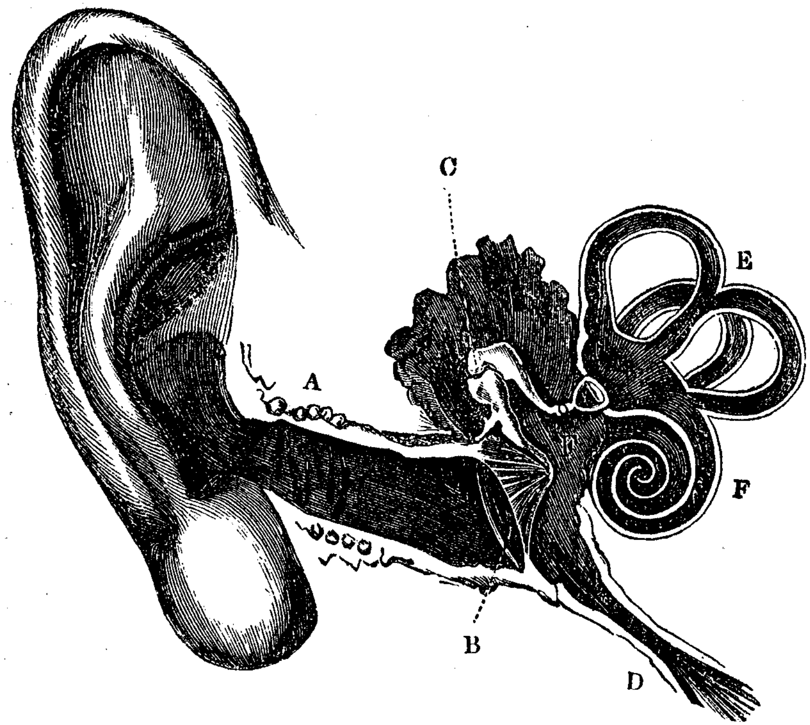
* This subject is touched upon in the introductory observations to the Appendix.

(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.[13] Its general form, however, both

[13] The reader will find a dissertation on the ear in the Appendix. Other authors, as well as Dr. Paley, have said that we do not understand the uses or mutual dependency of the internal parts of the ear: an observation either not very intelligible, or which shows them to have studied it superficially.

external and internal, is sufficient to show that it is an instrument adapted to the reception of *sound;* that is to

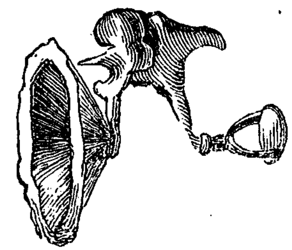


Explanation of the Plan of the Ear.—A, the tube of the ear, having little glands to secrete the wax, and hairs standing across it to exclude insects, without impeding the vibrations of the atmosphere; B, the membrane of the *tympanum* drawn into the form of a funnel by the attachment of the *malleus;* C, the chain of four bones lying in the irregular cavity of the *tympanum*, and communicating the vibrations of the membrane B to the fluid in the labyrinth; D, Eustachian tube, which forms a communication between the throat and the *tympanum*, so as to preserve an equilibrium of the air in the cavity of the *tympanum* and the atmosphere; E, F, the labyrinth, consisting of a central cavity, the vestibule; the three semicircular canals, E, and the *cochlea*, F.

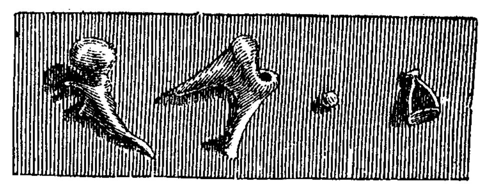
Beginning from the left hand we have the *malleus*, or say, already knowing that sound consists in pulses of the air, we perceive, in the structure of the ear, a suitableness to receive impressions from this species of action, and to propagate these impressions to the brain. For of what does this structure 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 thereof 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 movable and infinitely curious bones, forming a communication, 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

hammer, the first of the chain of bones; we see the long handle or process which is attached to the membrane of the *tympanum*, and which moves with the vibrations of that membrane; the other end is enlarged, and has a groove upon it which is articulated with the next bone. The second bone is the *incus*, or anvil, to the grooved surface of which the *malleus* is attached. A long process extends from this bone, which has upon it the *os orbiculare;* and to this third bone there is attached a fourth, the *stapes*, which is in shape like a stirrup iron. The base of this bone is of an oval shape, and rests upon a membrane which closes the hole leading into the labyrinth. This hole is called *foramen ovale*. The plan of the *cochlea* shows that one of its spiral passages, beginning in the vestibule, winds round the pillar till it meets in a point with another tube. If the eye follow this second spiral tube, it will be found to lead, not into the vestibule, but into the irregular cavity of the *tympanum*.

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 excited 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

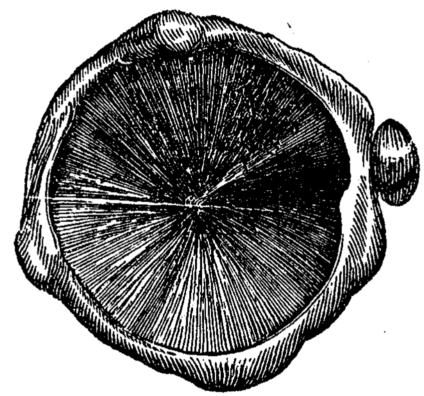


[This figure represents the bones which form the chain.]

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 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.[14]

The benefit of the Eustachian tube to the organ may be made out upon 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.

[14] It will be shown in the Appendix, that the fine apparatus consisting of these bones, with their four minute muscles attached to them, is not necessary to the sensation coming through the bones of the head, as here described by our author: it is provided for the more delicate vibrations of the elastic atmosphere, and is not found except in animals that breathe the air. It will be also found, that whilst these bones move with the slightest impulse of sound, they regulate the impression, and protect the nerve.



[This figure represents the membrane of the tympanum of a larger size than natural. It is represented as tucked in by the handle of the *malleus*. The description of Sir Everard Home, referred to in the text, is altogether fanciful. There is no proof that these fibres are muscular: they are drawn tight by the small muscle attached to the *malleus* called *tensor tympani;* and it would appear that these cords are necessary to produce that variety of motion in the membrane suited to all the variety of sounds which are conveyed through it to the seat of the sense. Sir Everard played to the elephant on the pianoforte. That the animal took some notice of the extraordinary sound cannot surprise us; but the inferences drawn by Sir Everard were equally ingenious and groundless. He supposed that the musical ear was owing to the membrane of the tympanum.]

The membrana tympani itself, likewise, deserves all the examination which can be made of it. It is not found in the ears of fish; 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 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.), Mr. 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 supposes 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 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 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.

ON 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 attention 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 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 further 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.[15]

[15] When we have, in some measure, comprehended the system of an animal body, how the different organs are related to each other, and how the whole exists through a mutual influence of its parts, the wonder is renewed how another creature should grow out of that, which, as far as we have seen, has no tendency to multiply itself. Authors who treat of reproduction, even to the very last, affirm, that with the germ of life in all organized structures are conjoined the seeds of decay and of death: they tell us that the powers of life are finite, and that the time must come when they shall be expended. Now there are no seeds of decay; and although, according to the law of animal existence, the individual perishes, it is incorrect to say that it is the result of the exhaustion of the powers of vitality, or the deterioration of the material which enters into its composition. We gain nothing by adapting the language of one science to explain another: it is of no advantage, in treating of life and death, to adopt a chemical nomenclature. The term of life in every creature, from the elephant to the ephemeral fly, has its limit; but it is wrong to say that it is by the defect

of the material, or of the energy of life: it is a better philosophy to admit that it is in accordance with the system which the Deity has ordained.

Life, in the sense in which it is used here, is continued in the germ that rises from the parent; since out of the old body, that is described as a deteriorated and useless material, a new creation is produced, it suffices to show that there is no necessary decay from the material itself. A leaf or twig of an old tree will strike root into the ground, and vegetate and exhibit youthful vigour. So will the fresh-water polypus furnish a portion which, being cut off, will grow with a perfect resemblance to the original stock. In the reproduction of the higher and the more complex organized bodies there is much that is obscure; but in the simpler, and, as it is termed, the lower examples—vegetables, zoophytes, and infusory animals—we have abundant proofs that the result does not proceed from the exhausted or deteriorated nature of the material.

Amongst the infusoria, the animals called *Monads,* of which there is a great variety, exhibit very curious phenomena. They are of a globular form, and this globe is seen first to contract and then divide, each becoming a distinct animal. And something like this may be done artificially by the division of the fresh-water polypus, or hydra; and what is deficient in the divided portion is supplied by a new growth, be it head or tail. The thing, however, is not so remarkable, if we consider that those lower animals have abundant resemblance to vegetables; and that in cutting off portions the experimenter is cutting off buds. These buds or tubercles, if left to undergo their natural changes, acquire independent motion, produce tentacula, or feelers, to procure food, and, thus prepared to be independent, fall off from the parent stock.

The microscope exhibits another instance in the *Volvox.* It is a transparent globule, within which smaller globules may be seen; and when matured the parent bursts, discloses the offspring, and dies.

In all these examples, we see that there is no reason to speak of exhausted or deteriorated matter, or debility in the powers of life.

So in the higher and the more complex animals we find one set of organs decaying and another rising into existence. Contemplating the one, we would say that the powers were decaying; contemplating the other, that they were fresh and

vigorous. We must come to the conclusion, then, that the growth of parts, or the period of their development, the decay of the animal, or of the parts of the animal, is by an ordinance which is very inaccurately expressed by the terms exhaustion of life, or imperfection of the material. Imperfection, in truth, is a relative term, and means failure or insufficiency towards the accomplishment of certain purposes. If the object in view were the duration of animal bodies for a great length of time, we might be justified in saying that the materials they are made of are imperfect; but this is clearly not the design with which they are formed.

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 provisions em-

ployed 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 a 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 cases; 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 suspension of their office destroys the life of the animal.[16] In this case, therefore, we may be said to know the use, nay, we

[16] Undoubtedly the exposure of the blood to the atmosphere, in the circulation through the lungs, and the throwing off of carbon, are essential to life. But the pain and alarm excited when there is danger of suffocation are not so much a direct consequence of the interruption of the function, as an instance of the manner in which the sensibility is bestowed to guard the important actions of life.

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 inconveniences 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 functions. 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 improvement 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 been never 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 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.[17]

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, or cartilage, &c. But that it should have been an *eye*, knowing as we do what an eye comprehends,—viz., that it should have consisted, first, of a series of transparent lenses (very different, by-the-by, 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

[17] In the higher animals there is a great complication of organs. Yet, in the lower animals, the functions of digestion, respiration, assimilation, secretion, and growth proceed by means of an apparatus comparatively simple. We must not be surprised, then, that certain parts may be removed from the higher animals without destroying life. But this does not imply that those parts are useless, since they are structures superadded for the finer adjustment of the different functions one to the other, belonging to a higher condition of the economy.

With regard to parts which are thus called useless, we must remember that the varieties of created animals belong to one type. As we have just said, the essential functions are the same in all; and there is much of the structure common to all: when an animal of a particular class has its organization adjusted to a certain condition of existence, we may see the rudiments of parts which, not being in action, are imperfect, and we must look to the individuals of another species or variety to discover them in their full development.

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 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 exigences:—that all this should have taken place, merely because something must have occupied these points on 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 to 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 organised body of any kind, answering a valuable purpose by a complicated mechanism, the effect of chance.[18] In no assignable instance hath such a thing existed without intention somewhere.

18 There is great inaccuracy, and indeed a very unphilosophical and superficial view of the subject, in these observations upon "*chance.*" Chance is merely an abridged form of expressing our ignorance of the cause or preceding event to which any given event may be traced; and nothing can be more inaccurate, or indeed more productive of serious errors in this very branch of science, than to speak of chance as a substantive thing or power. To take the most obvious instance: we say, in common parlance, that the dice being shaken together, it is a matter of chance what faces they will turn up; but, if we could accurately observe their position in the box before the shaking, the direction of the force applied, its quantity, the number of turns of the box, and the curve in which the motion was made, the manner of stopping the motion and the line in which the dice were thrown out, the faces turned up would be a matter of certain prediction, after a sufficient number of experiments had been made to correct the theory. It is only because we take no heed of all these things that we are ignorant what will be the event; and the darkness in which we are respecting the circumstances which regulate it, is called by the name of chance. Nor is it correct to say, that this or anything else is done without design. All we can mean by the expression is, that our design stops short at a certain point, and leaves the laws of nature to guide the rest of the operation. But such a position is manifestly quite inapplicable to the operations of nature.

Equally inaccurate is it, if not more so, to speak of a wen or a pimple, &c., as the result of any cause in the least degree different from that which produced the eye. These are pos-

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

sibly always, certainly sometimes, diseases; but they are the result of contrivance as clearly as the eye itself. The functions of the animal system, though acting in an unusual manner, yet acting according to rule, produce those phenomena. Indeed one of them, a pimple, is, in part at least, the result of the provision made for restoring the interrupted continuity of the skin, by a slight suppuration from which the granulation, or production of new animal fibre, takes place. The like remark applies to the cases of a clod, pebble, or liquid drop, also put in this passage. We have already adverted to the two first in a former note; the formation of a drop is in truth one of the phenomena of gravitation, and a very remarkable one.

fancies of painters, and the fables of poets, realised by examples. Or, if it be alleged that these may transgress the bounds 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.[19]

[19] No doubt men in different ages have asserted the possibility of all we see being made by chance; but we are not uncharitable when we say that no man ever believed it. It is easily shown, that, of all the varieties of fabulous animals which have been bred in the fertile imagination of the poet, not one could have lived. They want that relation and balance of the different organs, that provision running through the whole texture of the frame of the animal, which we see in the natural productions. The sphinx has wings, but no constitution of body to give these strength. The griffin, with its hooked bill, has no feathers to preen, and no substitute for teeth. The centaur has the body of the horse, but no mouth to gather appropriate food.

We may conclude, then, that these products of the imagination are altogether abortive, and only tend to prove how exact the relation must be of all the parts, and especially of the vital organs of an animal, in order that it may live.

As to the second position, that the animals which exist are the happy results of chance when thousands have perished by imperfection, the supposition is contradicted by the perfect and harmonious chain of beings forming the animal kingdom, in which there is no link interrupted, no interval implying the loss of any species.

But, moreover, the division of organised substances into animals and vegetables, and the distribution and 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, nor 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 workshop, as well as his 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."[20] 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

[20] We deceive ourselves in this matter: the dexterity which use gives, makes us apt to believe that the faculty is gained through the accidental possession of the instrument. But the difficulty is removed, if we make due comparison between man and other animals. In the former, it is intended that the faculty should be gradually developed; and the slowness with which perfection is attained leaves us in some doubt of the relation between the effort and the instrument used. But in the latter, all obscurity is removed: their propensities and instincts, and the use of their instruments are so perfect from the beginning, as to admit of no improvement. The fly-catcher requires no experience to adjust his eye, no second effort of his bill to correct the first. Whether it be the horn, or the tooth, or the sting, the disposition is given with it, and the mode of its action is prescribed. The spider weaves his web without improvement, or room for improvement. This subject is treated at some length in the "Bridgewater Treatise on the Hand," where the question is discussed, whether or not the possession of the hand is the source of man's superiority.

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 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 everything 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 Simson's Conic Sections.

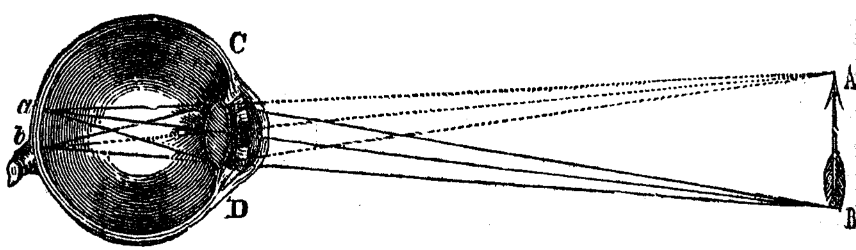
VII. Lastly; the confidence which we place in our observations upon the works of nature, in the marks which we discover of contrivance, choice, and design, and in our reasoning upon the proofs afforded us, ought not to be shaken, as it is sometimes attempted to be done, by bringing forward to our view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



[The figure is introduced to remind the reader of the fine adjustment of the eye; a subject explained in the Appendix :—A, B, is the object, and the lines represent the light reflected from it into the eye. On the surface of the cornea, which is the transparent part of the eye, the rays are in a certain degree refracted. Passing through the coat called cornea, they enter the aqueous humour. In their transmission through it, they pass into the pupil. They enter the lens or crystalline humour, and by the greater power of refraction in this humour, the rays are drawn to a point and impinge on the bottom of the eye at A, B. It will be further seen that the rays coming from B are refracted to *a*, those from A to *b*, and that the image is therefore represented inverted.]

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 action of the organ; the

provision in its muscular tendons 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 glands 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

* Again we have reference to the structure of the eye, which shows the necessity of throwing our observations on this organ into the Appendix.

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 shown, 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 of animals and vegetables.[21]

[21] The observation here is most sensible. When we speak of an organ as peculiarly suited to exhibit design, we mean merely that we comprehend something of the object of the particular structure. But there is no part of an animal, if we fully comprehended what was necessary to the performance of its functions, that would not raise our admiration. Were we to take a portion of the skin, and contemplate its exquisite sensibility, so finely appropriated—could we penetrate, as it were, into the pores, and duly estimate the power which regulates the secretions and absorption—could we fully understand the relations of this organ, either with the economy of the body within, or the constitution of the atmosphere without—we should have no occasion to draw our argument, for the twentieth time, from the structure of the eye or the ear. Were we to take one cell of the millions of that substance which, intervening between the more solid textures of the frame, gives elasticity to the whole, and permits circulation and muscular action, and all the various movements of the body, we should have in that one cell as much reason for wonder at the perfection of the contrivance, as in any joint of the limb.

[The reader will not be easily convinced that the mass of flesh, with which he is familiar, is easily and almost spontaneously divided into distinct muscles. This figure represents a muscle. C is the belly of the muscle; A and B the tendons: A being the tendinous *origin*, as it is termed, attached to a fixed point of bone; B the tendinous *insertion*, being attached to a part movable by the contraction of the muscle. The belly, C, consists of fibres, which are possessed of the power of contraction or irritability, and through the operation of which the various motions of the body are performed. We shall presently have to remark on the direction of these fibres.]

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, being assumed, 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—1st, 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 contraction of the tendons; 2ndly, 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; 3rdly, 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 required, 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 as accessible to inspection, as capable of being ascertained, as the mechanism of the automaton in the Strand. Supposing 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 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 the 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 a uniform pulp, milk, or mucilage. It seizes upon everything; it dissolves the texture of almost everything 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 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, 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, authorises us to draw in respect of a creative design? [22]

Another most subtle 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) 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 nutritious 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 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 every where 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 receptacle. This is all we know 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

[22] After this enumeration of the things dissolved by the gastric juice, the most extraordinary fact remains to be stated, that the delicate surface of the stomach itself, softer and finer than the surface of the eye, remains untouched by this humour, which our author, somewhat quaintly, describes as more powerful to dissolve than aqua-fortis. John Hunter showed us that it was the property of life that protected the coats of the stomach. This fact is a most singular proof of the power bestowed through life on the membranes and vessels; and it is as important as it is curious: for as the stomach in the dead body no longer resists this menstruum, it may become dissolved, if the person has died with the fluid already secreted into the stomach. And so it has happened that persons have been supposed to be poisoned; and relations have been falsely accused, from the stomach being found eroded as if some acrid poison had been taken before death.

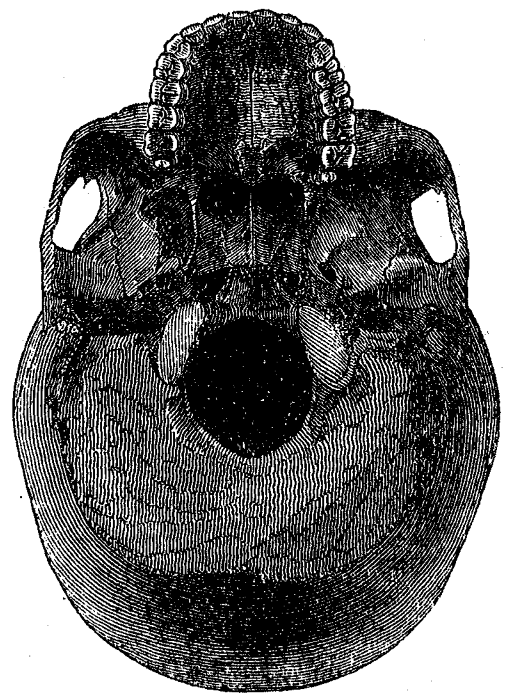
article from our argument, would be to dispose of the subject very hastily and very irrationally. For the purpose which we want, that of evincing intention, we know a great deal. And what we know is this. We see the blood carried by a pipe, conduit, or duct, *to* the gland. We see an organised apparatus, 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 or artery, *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 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 thrashing-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 unthrashed corn the thrashing-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 in 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 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 upper 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 bowel 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 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 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.

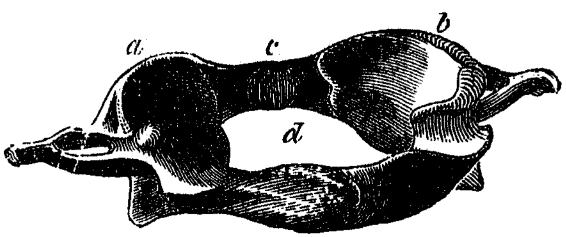


[This figure represents the lower surface or base of the skull. The hole is the *foramen magnum*, through which the spinal marrow descends into the spine; and on each side of the hole are the articulating processes, called the *condyles*.]

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.

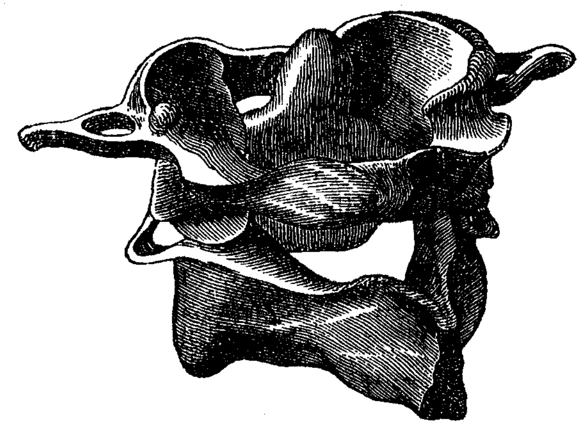
OF THE BONES.

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 part 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 further mechanism is introduced: not between the head and the uppermost bone of the neck, where the hinge is, but between that bone and the bone next underneath it. It



[This figure represents the uppermost vertebra, or atlas; and the condyles, mentioned in the former figure, sink into the articulating surfaces of this vertebra, permitting the nodding motions. *a* and *b* are the articulating surfaces; *c* is a surface which receives the tooth of the vertebra below; *d* the circle through which the spinal marrow passes.]

is a mechanism resembling a *tenon and mortise*. The 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 mortise, which runs between the first bone of the neck and the second.[23]



[Here the tooth-like process of the second vertebra, which is called *dentata*, is passed through the ring of the first, and is held there by a transverse ligament, like a spindle in the bush. No doubt the object of this complexity is to permit the free motion of the head, without too great a laxity at any one joining, and thereby to protect the most vital organ of the body, the *medulla oblongata*, or spinal marrow, which passes from the head into the tube of the spine.]

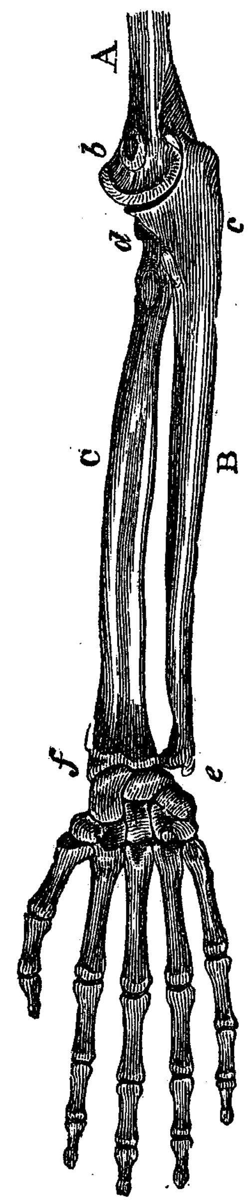
We see the same contrivance and the same principle employed in the frame or mounting of a telescope. It is occasionally requisite that the object-end of the instru-

[23] The meaning of our author is obvious here; but the tenon and mortise are terms used for the firm joining of beams, as in the carpentry of a roof; not for rotatory motion.

ment 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 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.

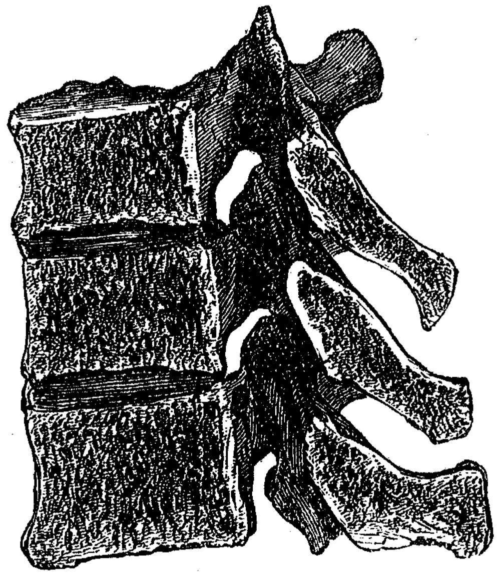
II. Another mechanical contrivance, not unlike the last in its object, but different and original in its means, is seen in what anatomists call the *fore-arm*—that is, in the arm between the elbow and the wrist. Here, for the perfect use of the limb, two motions are wanted: a motion at the elbow, backward 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, by touching only towards the ends. One, and only one, of these bones is joined to the cubit, 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



[Since it has been our author's pleasure to take this instance, the figure will illustrate his description. A is the lower part of the arm-bone, or *humerus*; B is the *ulna* and C the *radius*, the two bones of the fore-arm. It will be understood how these bones, being tied together by ligaments, hinge and move upon the humerus A; *c* being the process of the ulna, on which we rest when leaning on the elbow. By applying our hand to the arm, we at once feel the freedom with which the bone moves in bending and extending the arm.—When we turn the key in a lock, or make the guards in fencing by the motion of the wrist, the ulna B is stationary, and the radius C turns round upon the head of the bone at *d* and *e*, carrying the hand with it. The rest is abundantly well explained in the text.]

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 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 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 further 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



[This represents a section of three of the lower vertebræ. The subject being by no means exhausted in the text, the reader will find it taken up in the Appendix.]

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 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 in 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 while 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 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 surface 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, equidistant 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 vertebra 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 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 further fortifying expedient, in the mode according to which the vertebræ 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 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.

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 to the corresponding advantages which the body derives from it, for action, for strength, 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.[24] In the serpent tribe, however, it

[24] There is a notion entertained by the ingenious and somewhat fanciful physiologists of France, that the extre-

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 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

mities of the body, the parts furthest removed from the centre, are most subject to change in their conformation, whilst the central parts of the system are the most unvarying. Entertaining such a view, we lose much of the interest that is attached to the subject; and the inference which it is important to draw is forgotten, the accommodation not of parts only, but of the whole framework of the animal body, to the peculiar condition or necessities of the creature. The teeth vary because the food is different; the feet vary because the mode of progression is different; the claws vary in connexion with the teeth, and the mode of procuring food, by digging, or scraping, or by holding and tearing. So does the eye, and so does the ear. But with these adaptations of parts, we must not lose sight of the fact which is the most important to our conclusions—that the whole is accommodated, as well as the individual organs.

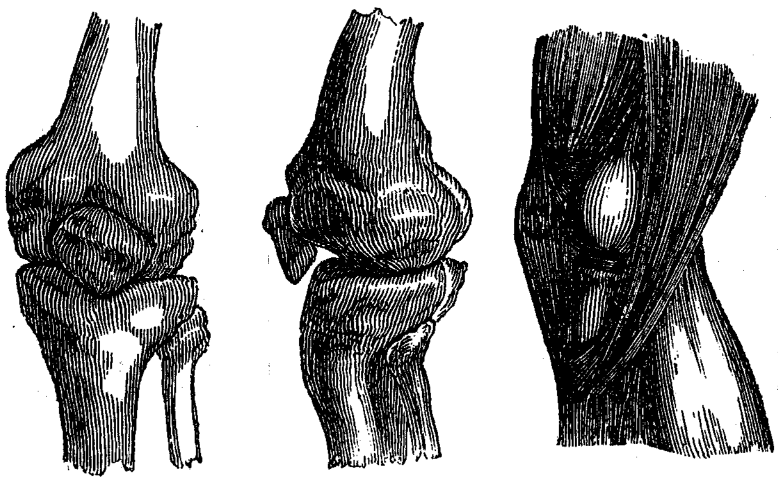
The spine in all vertebrated animals holds its office in perpetuity; it contains and protects the spinal marrow; and so far as its office is permanent, there will be an uniformity in its appearance in all creatures. But even in man it varies in its structure, in the different portions or divisions of it, as these portions are required to admit of more or less freedom of motion. In the hare, as mentioned in the text, the spine is beautifully accommodated to the motion in running. In the cat-kind, as the leopard or tiger, it has a lateral mobility, quite different from its structure in the horse or the stag. In the boar, the vertebræ are unusually firm, and the processes enormously extended, to give strength to the union with the head, and to direct the action of the muscles upon the head, so that he may tear up strong roots and possess his defence in his powerful tusks. In short, as far as the spine is required to accommodate itself to the motions of the trunk, it is varied with as fine an adjustment as the farthest bone of the toe or finger.

* Der. Phys. Theol. p. 396.

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 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, or rather 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 further 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. 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.[25]

V. The *patella*, or knee-pan, is a curious little bone: in its form and office unlike any other bone in 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 through it (or rather it makes a part of their continuation), from their origin in the thigh to their insertion



[Three views of the knee-joints.]

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 consider-

* Anat. p. 229.

[25] In the dissertation in the Appendix on the Thorax, it will be observed that we have additional proofs of the accommodation of the bones of the trunk, as well as of the bones of the extremities, to the varying habits and condition of the animal.

able 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, 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 hyoïdes); in strictness, it forms no part of the skeleton. It is bedded in the flesh, attached 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.[26]

[26] The shoulder-blade undergoes many changes, as we view it in comparative anatomy. That bone which we feel running across the upper part of the chest and lower part of the neck, the collar-bone, is properly a process of the shoulder-blade. (See the figure in the Appendix, No. 7, c, c.) Its purpose is to hold the shoulders apart, and to give strength to the arms, by throwing upon the arm the action

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 mortise-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 mortise 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 mortise 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

of the muscles of the chest. Accordingly, we find it in climbing animals, in those which require to swing themselves by the upper extremities, as the monkeys; but in animals that have a solid hoof, which implies that the anterior extremity is for the particular purpose of running or bounding upon the ground, not only is there no occasion for that variety in the motions of the extremity, which is produced by the introduction of this bone into the skeleton of the arm, but it would be injurious—it would deprive the animal of that elasticity with which it alights upon the ground. Where there is no clavicle—in the horse and deer, for example—the shoulder-blade, or scapula, is attached to the trunk by muscles alone. Hence when the animal makes a leap, it comes down upon the fore-legs with an elastic rebound, the trunk hanging upon the muscles, the muscles supported by the scapula, and the scapula sustained upon the bones of the extremity. There is no solid substance to receive the shock. Were the collar-bone introduced here, it would be snapped across by the percussion, as happens to a man when he is thrown upon his shoulder.

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 joints—*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 some important joints, 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 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, as it 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 our 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.[27]

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

[27] This ligament is absent in the orang-outang; and in the lower extremity of this animal there are other points of resemblance to the structure of the arm; and certainly the use of the hinder extremity corresponds with this structure, since he grasps and swings equally well with either extremity.

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, "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 wholly 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 liable 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.[28] Why should the tibia terminate, at its lower

* Ches. Anat. ed. 7th, p. 45.

[28] It is surprising, that among so many instances our author should omit to notice the perfection in the ankle-joint. When we stand resting upon the foot, the joint is firm, and yields neither to the inside nor the outside; but when we move the foot forward and point the toe in making the step, such is the happy form of the bones that the foot is in this position thrown quite loose. The object here certainly is, that in walking on the irregular ground, we may have a freedom in directing the foot so as to plant it securely. But before the weight of the body is brought perpendicularly over the foot, there is no danger to the joint, because there

extremity, with a double end, and the fibula the same—but to barricade the joint on both sides by a continuation of part of the thickest of the bone over it? The joint at the *shoulder*, compared 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 the 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 locomotion—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 dislo-

is no strain upon it. Just in proportion as the advancing body begins to bear upon it do the bones take that position, in which they are as firm as in the knee-joint itself, admitting only the motion of a hinge.

cated; 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 cliff, 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 ham-strings, 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 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

* Ches. Anat. p. 255, ed. 7.

† Ibid. p. 35. ‡ Ibid. p. 30.

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.[29] To me the surmounting 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 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,

[29] As the Archdeacon had been a pupil of Dr. William Hunter's, which we gather from the tenor of many of his observations, it is surprising that he has not spoken with more decision upon this point. The cartilage, which is the substitute for the bone in infancy, is very different from that which tips the ends of the articulating extremities of the bones. In a valuable paper of Dr. Hunter's, it is shown that this articulating cartilage consists of fibres, placed together like the hairs of a brush, but more compactly, and perpendicularly to the ends of the bones; and that on this arrangement chiefly depends the elasticity of the material. Its use is best proved by what takes place when it is deficient: for then the articulation creaks like an old hinge, and the patient suffers aches.

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, 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 at 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).[30]

* Ches. Anat. p. 13, ed. 7.

[30] This is not explained with our author's usual clearness. The lower head of the thigh-bone, which rests upon the shin-bone or *tibia*, is not the segment of a regular circle. When we stand with the knees straight, the thigh-bone rests with a broad surface, and the convexity is principally on the back part. Such an irregularity would make a very imperfect and jarring hinge-joint on any configuration that could be given to the corresponding surface of the tibia. Therefore these cartilages intervene; and, being possessed of considerable elasticity, and so connected with the bone as to shift their place a little, they accommodate themselves, whether the flatter end or the more convex part of the articulating surface of the bone be presented to them; and there is this advantage, that, in standing, when the weight on the joint is greatest, the thigh-bone has a more extensive, and

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 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 anything to last—for anything so much worked and exercised as the joints are. This durability I should attribute in part to the provision which is made for the 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.[81]

consequently a more secure basis, at the same time that the motion of the joint as a hinge is perfect.

[81] This subject is touched upon in the Appendix, in treating of the spine. We may here take a practical illustration

Movable 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 sometimes 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.

We have said that exercise is necessary to the perfection of a joint. Suppose the knee-joint to be inflamed: it is of course kept in perfect rest, because motion produces pain. This absolute rest, joined with inflammation, alters all the textures; the bone becomes light and spongy; the cartilage is absorbed; the ligaments which ought to hold the bones together become loose and relaxed; and what the surgeon calls consecutive dislocation may take place—that is, the bones will actually shift their place, from the defect of those attachments which ought to keep them together. Now, let us suppose the inflammation to have subsided: by due attention all may be restored; and by no other mode than moving the joint—the only precaution necessary being, that it shall be moved with a care and gentleness corresponding to its weakened condition. By this simple means the ligaments will acquire firmness, the cartilages smoothness, and the *synovia*, or lubricating mucilage, will be again poured out: from all which we see, that in the living animal textures, wear and tear do not take place upon continued motion; but, on the contrary, that exercise is made the stimulus to improvement. All other proofs of design, as adjustment, relation, compensation, prospective contrivance, are weak in comparison with this.

CHAPTER IX.

OF THE MUSCLES.

MUSCLES, with their tendons, are the instruments by which animal motion is performed. It 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 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 directions. 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 likewise so disposed as to be capable of steadying the globe as well as of moving it. The head of a new-born 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 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.[32] This is the nature of the

[32] Excellently well as this is put, there is something more

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 brachialis *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 brachialis *externus*, and the 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 ob-

admirable still in the condition of the muscular system. With respect to the support of the head, as mentioned in the preceding page, and the instance embraces, of course, the erect position of the body as well as the equable poising of the head, the most extraordinary part of the phenomenon is this, that we are sensible of the slightest inclination of the body or of any member, although it would be difficult to say to what order of acknowledged sensations this belongs. Not only do we feel every degree of inclination from the perpendicular in the poising of the body, but we act upon it with the most minute correspondence of the muscles. The muscles are antagonists certainly, but there is a fine combination and adjustment in their action, which is not illustrated by the two sawyers dividing a log of wood. The muscle having finished what we call its action or contraction, is not in the condition of a loose rope, but on the contrary there is always a perfect balance of action preserved between the extent of relaxation of the one class of muscles, and the contraction of the other; and there is a tone in both by which the limb may be sustained in any posture that is willed. This subject is treated in the Philosophical Transactions, and also in the Treatise on the Hand, under the head of the "Muscular Sense."

tains in all the limbs, and in every movable 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 order—*e. g.*, the mouth is holden in the middle of the face, and its angles kept in a state of exact correspondency, by two muscles drawing against and balancing each other. In a hemiplegia, when the muscle on one side is weakened, the muscle on the other side draws the mouth awry.

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 inconvenience; 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 embedded in one another, sometimes perforating

* Keill's Anatomy, p. 295, ed. 3.

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

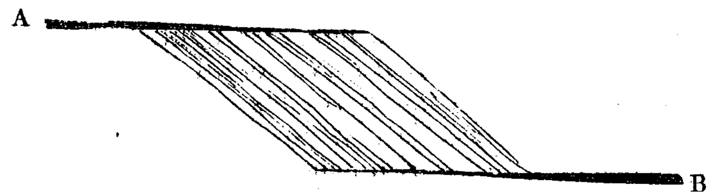
IV. The following is oftentimes the case with the muscles. Their action is wanted where their situation would be inconvenient. In which case the body of the muscle is placed in some commodious position at a distance, and made to communicate with the point of action by slender strings or wires. If the 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 unwieldy 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 lodged in the back part of the globe, where it lies safe, and where 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

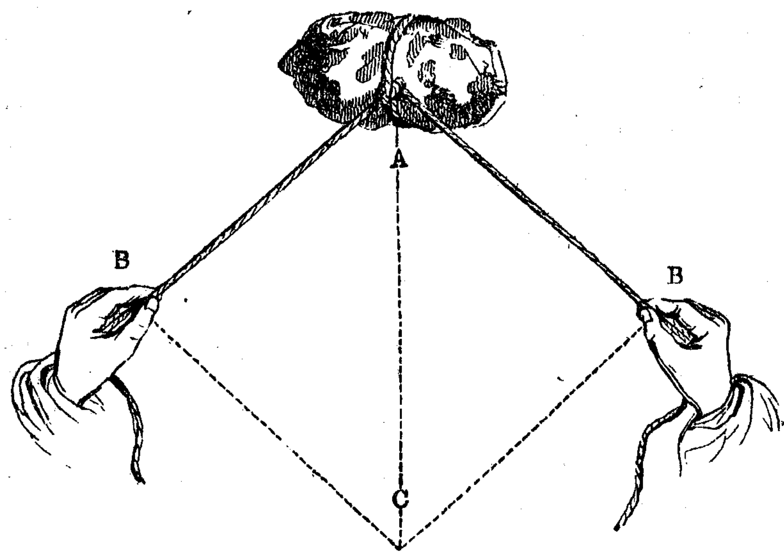
variety, whilst the original property of the muscle, the law and line of its contraction, remains the same, and is simple. Herein the muscular system may be said to bear a perfect resemblance to our works of art. An artist does not alter the native quality of his materials, or their laws of action. He 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.[33]

VI. The ejaculations can never too often be repeated—

[33] In the figure of a muscle, given in page 68, it may be observed that the tendons are on different sides of the muscle.



If we were to plan their arrangement it would be thus: A is the tendinous origin, and B the tendinous insertion; and the muscular fibres run obliquely between them. This obliquity of the fibres is almost universal in the muscles of



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 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

the limb, and the effect is very important. It needs no reference to mechanics to understand, that if we pull obliquely upon a weight we sacrifice a great deal of power. For what advantage, then, is power resigned in the muscle? "If you wish to draw a thing towards any place with the least force, you must pull directly in the line between the thing and the place; but if you wish to draw it as quickly as possible, and do not regard the loss of force, you must pull it obliquely, by drawing it in two directions at once. Tie a string to a stone A, and draw it straight towards you at C with one hand; then make a loop on another string, and running the first through it, draw one string in each hand at B B, not towards you, in the line A C, but sideways, till both strings are stretched in a straight line: you will see how much swifter the stone moves than it did before when pulled straightforward. Now this is proved by mathematical reasoning to be the necessary consequence of forces applied obliquely; there is a loss of power, but a great increase of velocity. The velocity is the thing required to be gained."[a]

[a] Preliminary Treatise on the Objects, Advantages, and Pleasures of Science. (Library of Useful Knowledge.)

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 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 (which is a great perfection of the organ) neither the

By the liberal employment of muscular power, quickness and variety of motion are obtained, and with the advantages which are so well described in the succeeding part of this chapter.

number, nor the complexity, nor what might seem to be the entanglement of its fibres, in anywise 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 meantime, remain defended from the rough action of the unbruised spiculæ.

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: 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 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 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 the 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.[84]

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 species of instrumental *music*,

[84] When our author describes the variety of functions performed by the mouth and tongue, he is in admiration at the simplicity of the instrument. But this is only an apparent simplicity: the complexity of structure is concealed. Indeed, it has been this very consideration which led to the new investigations into the nervous system. Without entering far into this subject, we take the tongue in illustration. It is a fine organ of touch: it is the seat of the sense of taste: it is necessary to deglutition: its modulations are infinite in speech; but the reason of a body so simple in its outward form being capable of performing offices apparently so discordant, is visible only to the anatomist, who traces the nerves into this organ. Then he discovers, besides the nerve proceeding from the papillæ of the tongue to the sensorium, that there are nerves of volition governing the muscles of the tongue. In addition to these, there is a nerve which regulates the action of swallowing, and which combines the motions of the gullet with those of the tongue; and in the same manner another nerve, tending to the organ of voice in the larynx, branches off to the tongue, and associates it with the organ of the voice, so as to produce articulate language: these nervous cords are the true organization by which one member, simple in its exterior form, has a complexity in its internal relations. And thus it is, that in many instances organs which are apparently simple, and through which we perform many offices so easily that we think not at all of what is necessary to their execution, have yet internally, and to the eye of the anatomist, a thousand minute circumstances or relations on which the perfection of their action depends.

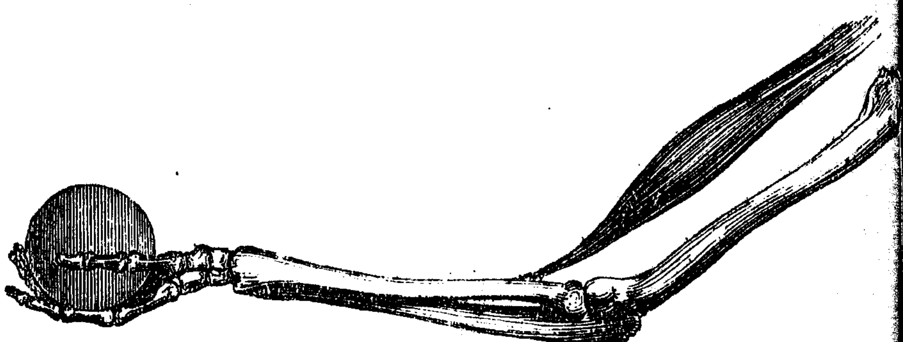
in which the changes produced by the hand of the musician are exceedingly rapid; are exactly measured, even when most minute; and display, on the part of the muscles, an obedience of action alike wonderful for its quickness and its correctness.

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 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 contractions, definite, both as to the choice of the tendon, and as to the space through which the contraction 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 hand-writing 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 be 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, 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 semivoluntary 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 contraction of tendons pulling in the direction of the sides of the parallelogram. This is the case, as hath been already 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 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. Mr 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



[The figure here represents the action of the biceps muscle which lies on the arm, and is *inserted* upon the radius of the fore-arm in sustaining a weight in the hand.]

* Phil. Trans. part i. 1800, p. 8.

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 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 motions 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 hyoïdes, 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."

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, 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 to 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 re-

* Ches. Anat. p. 119.

sources 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 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 collocation 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 including 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

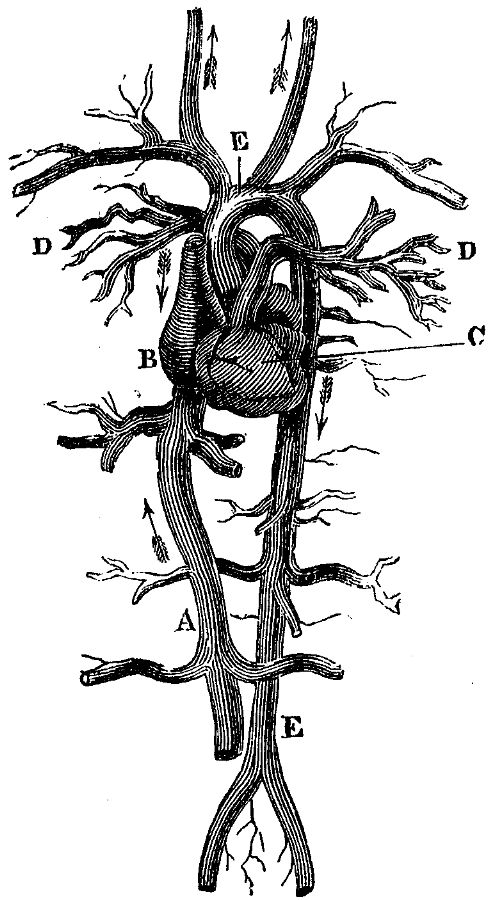
sharp lines, in the configuration of hard materials, in the moulding, chiseling, and filing into shapes of such articles as metals or wood. There is something therefore of habit in the case; but it is sufficiently evident that there can be no proper reason for any distinction of the sort. Mechanism may be displayed in the 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 minùs arida est legentibus quàm inspectantibus fuerit jucunda eorundem præparatio. Elegantissima enim mechanicês artificia, creberrimè in illis obvia, verbis nonnisi obscurè exprimuntur: carnium autem ductu, tendinum colore, insertionum proportione, et trochlearium distributione, oculis exposita, omnem superant admirationem."

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

CHAPTER X.

OF THE VESSELS OF ANIMAL BODIES.



[The figure represents the heart and great blood-vessels, and may convey some idea of the circulation of the blood. We understand A to be the great vein returning the blood from the body; B the right sinus

or auricle. From this cavity of the heart the blood is carried into C, the ventricle; and from this ventricle the pulmonary artery goes off. This great artery of the lungs is for the conveyance of the blood which is returned from the body into the lungs. Now the great vein A, the auricle B, the ventricle C, and the pulmonary artery D D, belong to the right side of the heart; or, to take a more important distinction, they convey dark-coloured blood, which is unfit for the uses of the system. But when this blood reaches the lungs, and is exposed to the atmosphere we breathe, it throws off the carbon, becomes bright in colour, and is called arterial blood. It returns to the heart, not to the cavities which we have enumerated, but by the veins of the lungs to the other side of the heart, the left—that is, to another auricle and another ventricle. From this left ventricle there ascends the aorta, the great artery of the body, E E. This great vessel conveys the blood to every part that has life. From all the parts of the body the blood is gathered again by the extremities of the veins, and so returns to the point of the auricle from which we began to trace it. This short preface may make the observations of the author easily intelligible.]

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 subtle and intricate—nay, it is possible that in their 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.[35]

This system presents itself under two views: first, the

[35] We must refer our reader to the dissertation in the Appendix, on the circulation of the blood and its uses.

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 as 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 subdivided streamlets, first by capillary ramifications into larger 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 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 greater 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 further 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 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. 117, ed. 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 in every four minutes."

Consider what an affair this is, when we come to very large animals. The aörta of a 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 a whale: "The aörta 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;[36] 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 pure ingredient, and at the same time gives

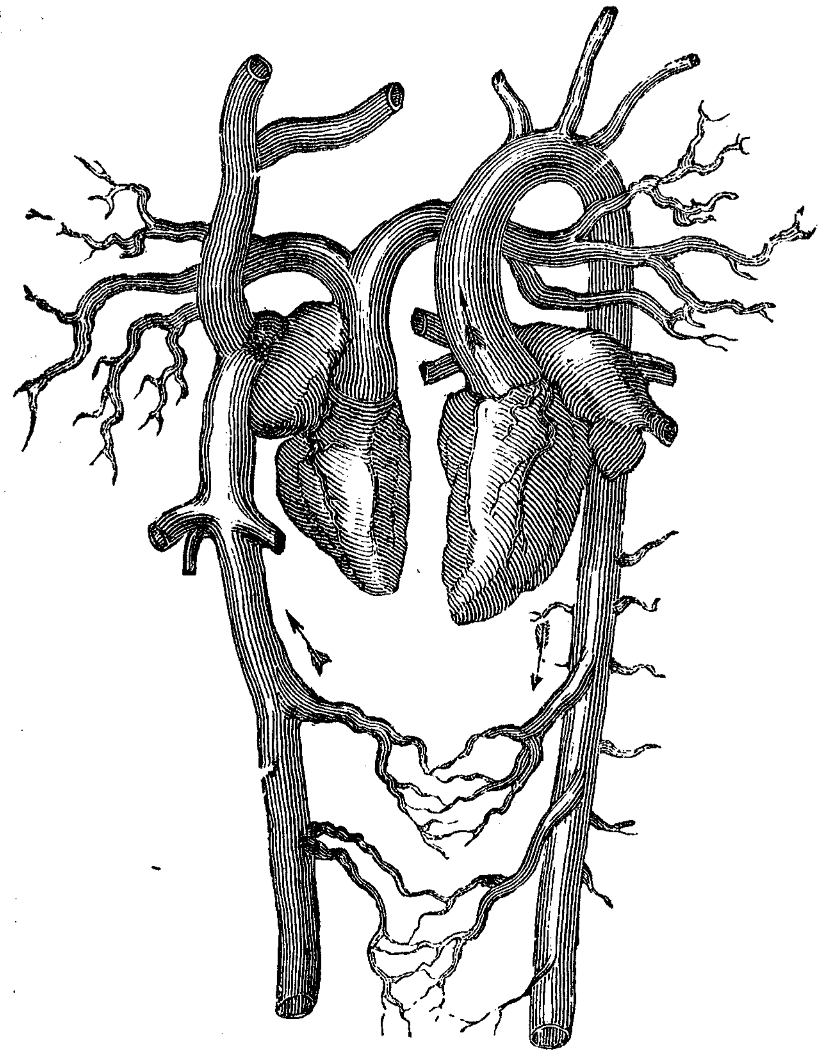
[36] The atmosphere contains, in every 100 parts, of oxygen 21 parts; nitrogen or azote, 79 parts; carbonic acid gas, a fractional part.

† Dr. Hunter's Account of the Dissection of a Whale.—(Phil. Trans.)

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.[87] The lungs of animals are constructed for this purpose. They consist of blood-vessels and air-vessels, lying close to each other; and whenever 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 the air to the blood depends, would, if collected and expanded, be, in a man, equal to a superficies of fif-

[87] The most simple view, and the best supported, is this—that the dark venous blood which is returning from the circulation through the body is loaded with carbon. When it is carried to the right side of the heart, and from that into the lungs, the branches of the pulmonary artery are distributed in great minuteness on cells infinite in number. These cells communicate with the extreme branches of the windpipe; and as the atmosphere is received into these cells, the circulating blood comes to be exposed to its influence; for neither the coats of the minute vessels which contain the blood, nor the fine membrane of the cells which contain the air, prevents the influence of the atmosphere upon the blood. The carbon of the blood meeting the oxygen in the atmosphere, forms carbonic acid gas; and the air expelled in expiration, thus loaded, carries away, of course, a portion of moisture by exhalation. (See the dissertation entitled—On the Circulation. Appendix.)

* Keill's Anatomy, p. 121.



[The figure represents the two sides of the heart separated: that to the left of the figure, but on the right side of the body, containing the venous blood which must pass through the lungs to serve the purposes of the economy; and that on the left side containing arterial blood, which is sent out into the body. Man, and all animals of warm blood, have the whole mass of blood passing through the lungs, and a double heart, as here represented, each consisting of a vein, an auricle, a ventricle, and an artery. The arrows point out the course of the circulation.]

G 2

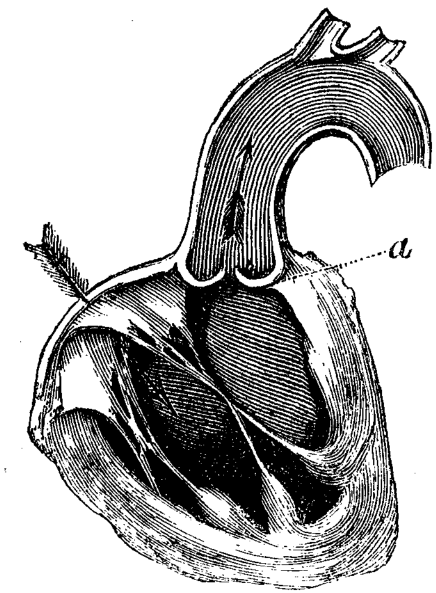
teen feet square. Now, in order to give the blood in its course the benefit of this organization (and this is the part of the subject with which we are chiefly concerned), the following operation takes place. As soon as the blood is received by the heart from the veins of the body, and *before* that 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 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, compel 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!



[This figure will assist the explanation of the following pages. It presents a section of the ventricle and the artery. Suppose that the blood enters in the direction of the arrow, it passes between two valves, of very particular construction. They are of a triangular shape, and held out by little cords, which are called the *cordæ tendineæ*. These cords are attached to muscles, which, from their appearance, are called *columnæ carneæ* and these fibres are continuous with the fibrous substance of the heart itself. Now when the ventricle is distended with blood, the valves are drawn by their tendons in such a manner as almost to close the orifice; and certainly so to dispose them, that the instant the blood takes a direction backward into the vein by the contraction of the ventricle, they fall together, and like a flood-gate stop the current in that direction. Were there no *cordæ tendineæ* or *columnæ carneæ*, these valves would be floated back into the auricle, and lose their office. But the most admirable part of the contrivance is, that the *columnæ carneæ* receiving the same impulse to contract as the walls of the heart itself, act at the same instant with it; and by contracting in proportion as the walls approach each other, they hold the margins of the valves like the leeches of a sail when bagged by the wind. The blood being prevented passing backward is urged into the great artery still in the direction of the arrow. And now it will be observed that the artery must be dilated when the heart contracts. And the artery itself being both elastic and muscular, reacting upon this impulse, it will contract while the ventricle is dilating. The blood would fall back from the great artery into the ventricle, were it not again prevented by the mechanical intervention of valves. *a* represents the semilunar valve of the aörta at the root of that great artery; and it is a surprising thing to see how offices so nearly alike are performed by a mechanism entirely different. This valve consists of three little bags, which are driven up by the force of the blood in the natural course of the circulation; but when, by the action of the aörta, the blood makes a motion backwards, it fills these three little bags, and they fall together, and prevent the blood flowing back into the heart.]

But further: 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.

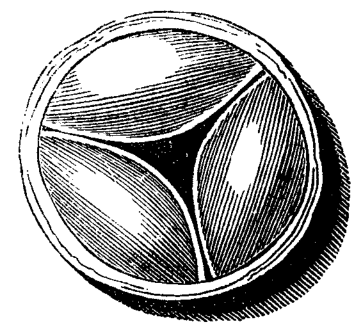
The heart, constituted as it is, can no more work without valves than a pump can. When the piston descends in a pump, if it were not for the stoppage by the valve beneath, the motion would only thrust down the water which it had before drawn up. A similar consequence would frustrate the action of the 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 vessel, and consequently allowing an open passage while the stream runs one way, but thrust out from the side by the fluid getting behind it, and opposing 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 passage; 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 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? [38]

[38] We cannot resist following up these observations with some minute notices of the appropriate structure. A sail distended with the wind would be torn up, were not the margins secured: accordingly, the canvass is folded over a strong cord, which is called the bolt-rope. So the margins of these semi-lunar valves are as finely finished as any sheet from the dock-yard. There is a ligament which runs along the margin, and strengthens it to sustain the impulse of the back-stroke of the artery. And were those *cordæ tendineæ*, which we have described as like the leeches of a sail, attached to the corner of the mitral valve without further security, they would be torn off on the first pulsation. But as the leeches are secured to the bolt-ropes of the sail, so are the *cordæ tendineæ* continued into firm ligamentous cords which strengthen the valves.

Our author says well, that the valve is thrown down on the side of the artery when the blood is in its course. But were this really the case, the refluent blood would not easily catch the edge of the valve to throw it up. Now this difficulty is met very curiously, and in two different modes. The *cordæ tendineæ* prevent the margins of the mitral valve within the ventricle from flapping close against the side of the cavity; and as to the semi-lunar valves at the root of the great artery, they are prevented falling against the walls in another mode: the section of the artery at its root is not a regular circle; but it is formed into three little bags or

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 proportional 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

sinuses, and as each of the three valves has a little sinus behind it, its margin never reaches the wall of the artery. The consequence of which is, that in the instant that the column of blood takes a retrograde direction, the margins of the valve are caught, and they are thrown up to close the passage. Nothing can be more admirably mechanical.



Since our author has so properly insisted upon the mechanism of the heart as the very strength of his argument, we shall mention one circumstance more as showing what may be called the perfection of the workmanship. It has been explained that the valves of the great artery consist of three semicircular membranes. Now if we consider the effect of these three semicircles meeting, there must be a triangular space in their centre, an imperfection in the point of their union as it were. To remedy this defect, on the centre of the margin of each valve, there is a little body like a small excrescence or tongue: and when these three bodies meet, they exactly fill up the triangular space which is left in the centre of the three semicircles. It is as if an ingenious workman had contrived a thing the most apposite to remedy a defect.

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 bowels; 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 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 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 horsehair.

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.

III. 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 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. 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, further 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 this 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 compared. 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 two table-spoons 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 route can be exhibited to the eye; nothing is left to be supplied by imagination or conjecture. Now, besides the subserviency of 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 nowise necessary; but in order to allow time and space for the successive extraction of the chyle from the digestive 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 up of contractions following one another like waves upon the surface of a fluid, and not unlike what we observe in the body of an earthworm 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 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 veins. Thirdly, it was necessary that these tubes, which we denominate lacteals, or their mouths at least, should be made 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 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 upwards, 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 in 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 the 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 of the *neck?* Who could have 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 Abbé 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 alimentary substances in the same manner as the gastric juice acts.

3. Digestion is not *putrefaction;* for the digesting fluid resists putrefaction most pertinaciously; 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 particular 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.[39] 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 membranous 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 Abbé. 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. Mr. 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

[39] One of the many modes by which seeds are carried to a distance, and Sir Joseph Banks gave us reason to believe that it served as a preparation for sowing, as seeds so carried germinated sooner.

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

But to return to our hydraulics.

IV. 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 position 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.[40]

[40] On this passage some remarks on the absence of the gall-bladder in certain animals might be required; but the

* Phil. Trans. vol. lxii. p. 447. † Keill's Anat. p. 64.
‡ Anat. p. 164. § Keill (from Malpighius), p. 63.

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 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.

V. Amongst the *vessels* of the human body, the pipe which conveys the saliva from the place 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 secreted juice 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

reader may turn to the note in the Appendix on the stomach of the horse.

* Keill's Anat. p. 62.

† Ches. Anat. p. 260.

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.

VI. 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, 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 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 anything 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, nevertheless, 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 windpipe 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 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 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.[41]

[41] Our author touches here upon the sensibilities which govern the motions of the chest—a subject which might be enlarged upon to fill a volume. But considering the object of this work, we ought not to omit the occasion of observing the union of a property of life with the most complex mechanical structure imaginable. We have seen, in former notes, that for the grand and vital purpose of decarbonizing the blood, the atmospheric air must be drawn deep into the lungs; and the problem is, to permit the vital air to pass, and yet prevent foreign matter from finding access. On this subject there is a note in the Appendix. But the more remarkable circumstance in connexion with the statement in the text is, that the whole of this apparatus for respiration is taken from the governance of the will, and placed under a power more constantly vigilant and more absolutely peremptory. The sensibility about the glottis holds in control a hundred muscles; and whilst it excites the action, directs the force of the stream of expired air with extraordinary exactness to the very point where the irritating matter lodges,

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 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.[42]

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;

be it in the passages of the throat, or in the cavities of the nose. There are many instances of the same kind in the economy of the frame, where actions are excited by sensibilities seated in certain spots, some of them attended with suffering, by which our voluntary efforts are brought in aid, and others where there is neither sensation nor volition, and yet the muscles are controlled and regulated, and the offices performed, with undeviating precision.

[42] The subject admits of a much more extensive application of physical science; and one division of it will be found treated in the Appendix.

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 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 further 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.

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, exhalents, 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. 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:—

1. 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 line—as the nose, the tongue, and 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 the 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 divides 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 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 of 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 aörta, 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 *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 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

* Ches. Anat. p. 184, ed. 7.

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 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 two soft lobes of the lungs; is *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 lobe 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

* Keill's Anat. p. 107, ed. 3. † Ib. p. 119, ed. 3

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 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 navel 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 bowels contained in the lower belly.†

7. The *spleen* also is confined to its place by an adhesion to the peritonæum and diaphragm, and 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.[48]

* Ches. Anat. p. 162. † Keill's Anat. p. 57.

‡ Ches. Anat. p. 167.

[48] Our author has not failed to fall into the snare which lies in the path of the adventurous theorist. We have here a new theory of the spleen. The spleen in truth has a double office: it is ever found attached to the digesting part of the intestinal canal; and is reasonably considered to afford occasional increase of circulation to the stomach, and to supply blood to the liver of that quality which appears necessary to a copious secretion of bile.

8. The *omentum*, epiplöon, 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 the organ from pressing with too great a weight upon another part. The processes of the 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 intermix with 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

* Ches. Anat. p. 167.

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 process, 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 holding, 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 lympheducts, 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 further observation will be necessary to show how well these things

* Keill's Anat. p. 45.

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 muscle 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 immediately under the skin; is a kind of lining to it; is moist, soft, slippery, and compressible; everywhere filling up the interstices of the muscles, and forming thereby their 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 tints 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.

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.

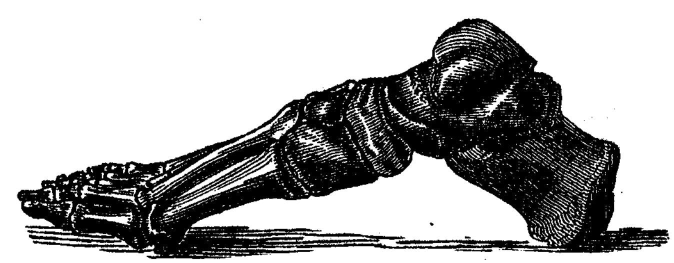
In plants, especially in the flowers of plants, the principle of beauty holds a still more considerable place in their composition; is still more confessed than in animals. Why, for one instance out of a thousand, does the corolla of the tulip, when advanced to its size and maturity, change its colour? 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 tints, 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 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 a 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 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 to 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 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.[44]

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.

[44] All this is admirably well put by our author. Yet when he says "the gift consists in the faculty of perpetually shifting the centre of gravity, by a set of obscure, indeed, but of quick balancing actions," he states a fact, but omits the most surprising circumstance of all. No doubt such efforts are made; but what directs them? If a man should balance a staff, resting it on the point of the finger, he shifts the finger continually, in doing which he is directed by the eye—he sees the staff inclining. How does a man judge of the inclination of his body in the very first degree of deviation from the perpendicular? He does not see himself, nor is he directed by the objects around him, since a blind man will stand as securely as one who sees. The fact is, that he has a knowledge of muscular action—a sensibility to the finest adjustment of the muscles, by which he directs their efforts. This sense is of all the most marvellous: a sensibility to an internal motion, more minute and curious than are the sensibilities to external impression; and which, as may be easily proved, ministers to a variety of properties in the living body, and especially to the organs of sense themselves.

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 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.[45]

2. The scarf-skin, which clothes all the rest of the body, gives way, at the extremities of the toes and

[45] See the dissertation on the teeth, in the Appendix.

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.[46]

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.[47] 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.

[46] The human nail is calculated to support the cushion of the extremity of the finger, and is important to us in grasping or holding any thing; but more so still in sustaining that cushion as the chief organ of touch. There are other parts of the body which have exquisite sensibility, yet they are not provided so as to give us that information of the condition of matter which we have through the finger, and in a lesser degree through the whole inner surface of the hand. We easily feel, for example, the pulsation of the artery at the wrist, through the combination of the sensibility of the nerve of touch with the elastic cushion of the finger. The best proof of the use of the elastic cushion is this:—Although the tip of the tongue feels so exquisitely that the presence of a hair of wool troubles us, yet if we apply it to the pulse we shall not be sensible of the beat.

[47] There is a note upon the form of the skull in the Appendix, which may interest the reader.

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 a plan and such adaptation, the strongest evidence that can be afforded of intelligence and design: an evidence which the 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, 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 subserviences to special occasions and utilities.

1. 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 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 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, in 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 in 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 anything equally perfect, if we had never seen it, or can now imagine anything 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 further 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.*

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, or 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

* 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*.

a feather cannot help taking notice, that the threads or laminæ of which we have been speaking, in their natural state, *unite*—that their 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 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 violence, 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.[48] It is further likewise remarkable, that this is not

* The above account is taken from Memoirs for a Natural History of Animals, by the Royal Academy of Paris, published in 1701, p. 219.

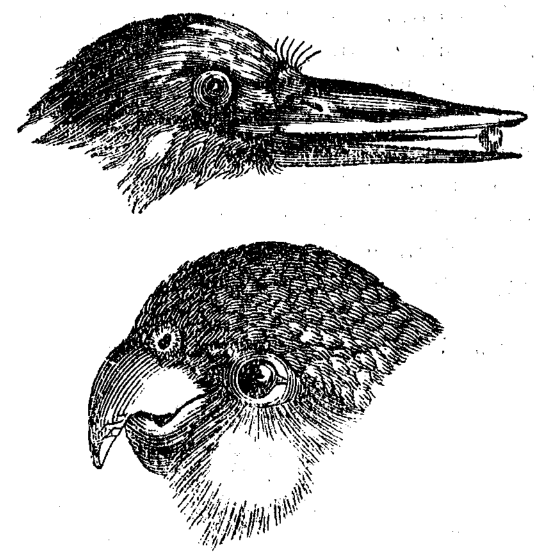
[48] When we attempt to apply the lights of experimental philosophy to this subject, the inquiry is not a little embarrassing. A loose woolly texture, or down, as it implies the presence of air in its interstices, air being a bad conductor of heat, is therefore a warm covering: it prevents the expenditure of animal heat. When we consider the colour of the coverings of birds, we must take new elements into our process of reasoning—we must reflect on the effects of the conduction and radiation of heat. The conduction is the conveyance of heat; and the radiation is the parting with it into the atmosphere or into space. We have already ex-

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 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 flat-

plained why the interior covering of the arctic bird should be loose: as to the colour, its effect must result from radiation. It appears (to use the vulgar language) that the influence of cold both on quadrupeds and birds is to increase their woolly or downy covering, and, in many instances, to change the exterior colour to white: in other and more correct words, a provision is made for changing their clothing so as to suit their altered circumstances. This change of colour corresponds with philosophical experiments—a white surface absorbing the least, and radiating the least, it should therefore tend to confine the vital heat within the animal, and carry it off slowly to the atmosphere.

ness, 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 plough-share, 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.[49]

[49] With the instrument, as we have before hinted, we

But the species of bill which belongs to the 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,

should expect a particular instinctive action, and a corresponding muscular power. As an animal with horns has a powerful neck, so has the neck of the heron, which is introduced here, an extraordinary muscular power, without which, indeed, the long and sharp bill would be of little use. When the dog approaches the wounded heron, the bird throws itself upon its back, and, retracting its long neck, suddenly darts it out with a force which strikes the bill deep into the dog. If you hold your hat towards the bird, the bill will be struck quite through it. In contending with the hawk, when the latter is spitted, it is not by the rapid descent of the hawk, but by the force with which the heron drives its bill.

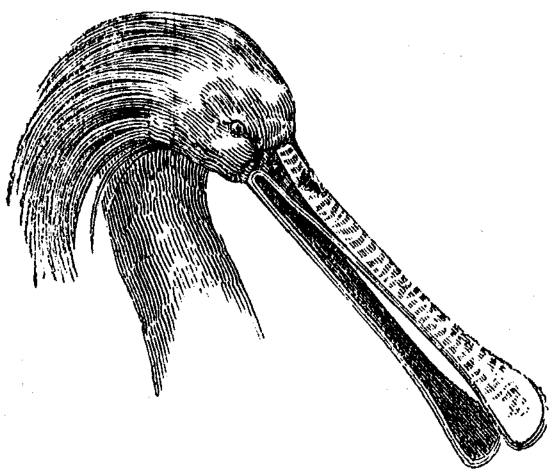
The strength of the bill of the parrot, and that of all birds which break the stones of fruit, or nuts, or hard seeds, is in another direction: the bill is hooked, yet is differently formed from that of the carnivorous bird. The intention is, in the first place, that the point shall play vertically, which, with the strengthening of successive layers near the point, enables it to break hard materials; and secondly, that by this form the nut or seed may be brought nearer the joining or articulation of the jaw, which gives the same advantage that we have when we put a nut nearer the joint of the nutcracker, that is, nearer the fulcrum.

One disadvantage of this form and shortness of the bill would be, that the mandibles could not open wide enough to take in a large seed; but it is provided that the upper mandible shall move upon the skull as well as the lower one, a subject which has not escaped our author's attention.

The form of the bill of the cross-bill, which he mentions, looks like an imperfection, but is attended with real advantages. It is not for crushing, but rather for splitting up a seed into halves, and tearing the cones of the fir-tree.

One of the most curious provisions is in the bill of the sea-crow. The mandibles are compressed into the form of simple laminæ, and the lower mandible projects beyond the upper one; so that, as he skims along the water, he dips his bill and lifts his food by the most appropriate instrument.

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 semi-liquid 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 and 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, 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.[50]

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 quadrupeds, 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. Everything 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

[50] These are branches of the fifth nerve of the head, which alone, of all the nine nerves of the brain, bestows sensibility on the organ of touch.

into a pump or sucker, fitted at the end sometimes with a wimble, sometimes with a forceps; by which double provision, 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 semi-lunar valves, found in the human intestine, are wanting in that of brutes. These are wrinkles or plates 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 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

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

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 *propriety* 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 is 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 or 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.[51]

[51] We have thrown some observations upon this subject into the Appendix, under the title of "The Relation of the Bodies of Birds to the Atmosphere."

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 intervals. 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.[52]

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 foreleg 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

[52] It has been elsewhere observed, that when predatory birds gorge themselves, they are sometimes unable to rise on the wing—a sufficient demonstration that the burden of an offspring would have unsuited them for flight.

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 skylark 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 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 remark-

able. 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 fish.[58] 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 confirmation of what we assert. In most fish, besides the great fin, the tail, we find two pairs of fins upon the sides, two single fins upon the back, and one upon the

[58] This subject is necessarily treated at length in the Bridgewater Treatise of the Hand. We have had occasion to state, that in the higher division of animated nature, the vertebrata, one plan or system of bones can be traced through every variety from man to fishes; and this is more especially shown by the comparison of the arm with the anterior extremity of quadrupeds and the wing of birds, and even with the pectoral fin of the fish. The number of the bones and the form and the application of the muscles to them vary, but yet they are accommodated in a manner so perfect, that, on examining any individual among the varieties of the species, we should say that nothing could be better suited to its purpose.

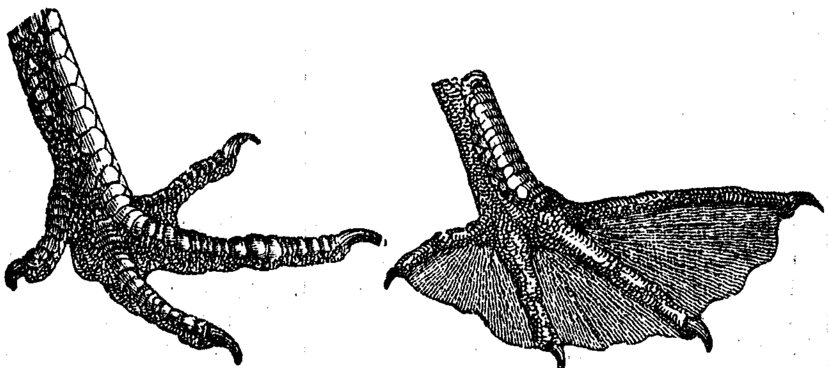
belly, or rather between the belly and the tail. The *balancing* use of these organs is proved in this manner. Of the large-headed fish, if you cut off the pectoral fins—*i. e.*, the pair which lies close behind the gills—the head falls prone to the bottom: if the right pectoral fin only be cut off, 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 more 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 forward 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 similitude 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 it is in other fish, is horizontal; its stroke, consequently, perpendicular to the horizon, which is the right direction for sending the fish to the top, or carrying it down to the bottom.[54]

* Goldsmith, Hist. of An. Nat., vol. vi. p. 154.

[54] The poising and motion of fishes in the water has interested some of our greatest philosophers, as Galileo and Borelli. It is estimated that fishes make their way through a medium which resists nine hundred times more than the atmosphere. But then, as it offers a certain resistance to their progress, it resists also the motion of their tail and fins by which they have their power of progression. The breadth of the tail of fishes, compared with that of their fins, and its muscularity and power, declare what is affirmed to us upon authority—that the tail is the great instrument of their progression; and we can see that when the trout darts away, the force of his motion lays down the fins close upon his body. But the fins direct him, as out-riggers, and the pectoral fins especially, by raising or depressing the head, give direction to the whole body under the force of the tail. The lateral fins, and particularly the pectoral fins, also sustain him in the right position in the water: without the co-operation of these with the tail, the fish would move like a boat sculled by one oar at the stern. As the digestion of fishes, as well as that of other animals, is attended with the extrication of air, and as the intestines are below the centre, the belly would be turned up but for the action of these lateral fins; as we see takes place in a dead fish. The tail and fins are the instruments of motion; but the incessant action of the muscles which move these is a just matter of admiration. If a fish move with his head down the stream, he must move more rapidly than the water, or the water gets under the operculum of the gills, and chokes him. He lies, therefore, continually with his head to the stream. We may see a trout lying for hours stationary, whilst the stream is running past him; and they seem to remain so for days and nights. In salmon-fishing, the fly is played upon the broken water, in the midst of the torrent, and there the fish shows himself rising from a part of the river where men could not preserve their footing, though assisted by poles, or by locking their arms together. When the salmon leaps, he makes extraordinary exertions. Just under the cataract, and against the stream, he will rush for some yards, and rise out of the spray six or eight feet; and amidst the

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 swim-



noise of the water, they may be heard striking against the rock with a sound like the clapping of the hands. If they find a temporary lodgment on the shelving rock, they lie quivering and preparing for another somerset, until they reach the top of the cataract. This exhibits not only the power of their muscles, assisted by the elasticity of their bones, but the force of instinct by which they are led to seek the shallow streams for depositing their eggs.

The porpoise will swim round and round a ship which is sailing at fourteen miles an hour: a thing almost as surprising as the fly circling round the horse's ear for a whole stage.

To all this may be added, that the solid which mathematicians have discovered, by refined application of the calculus, and have termed "the solid of least resistance," because it is the conformation which is less than any other affected by the resistance of any medium, resembles a fish in its form.

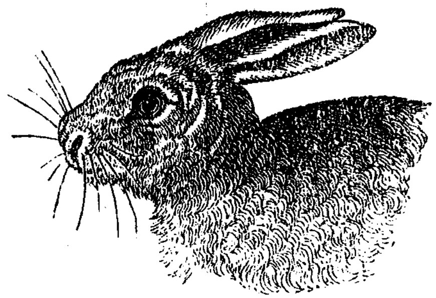
ming, as carried on by a bird upon the surface of the water, that should generate a membrane between the toes. As to that membrane, it is an exercise of constant resistance. The only supposition I can think of is, that all birds have been originally water-fowl, and web-footed; that sparrows, hawks, linnets, &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.

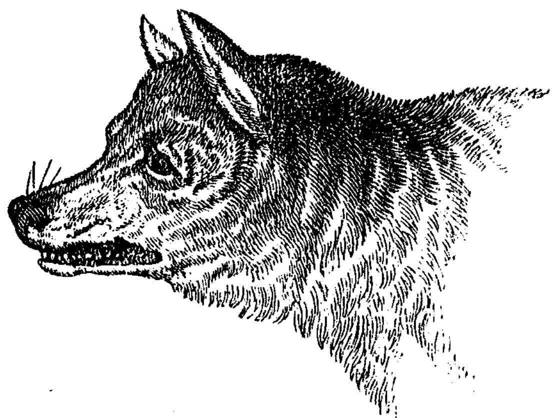
IX. The *five senses* are common to most large animals; nor have we much difference to remark in their constitution, or much, however, which is referable to mechanism.

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 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

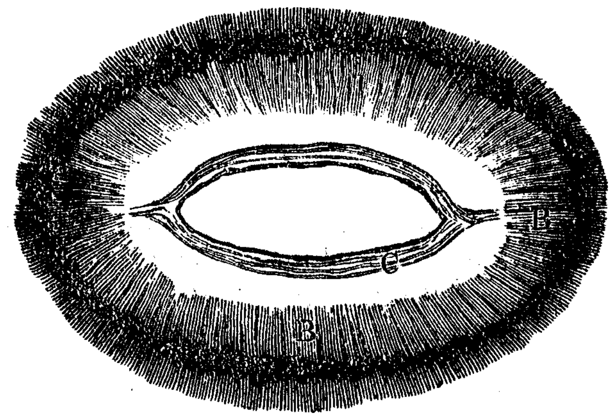




its being effected by the most feeble impulses. But that tenderness of structure, which rendered the membrane thus exquisitely sensible, rendered it also liable to be offended by the access of stronger degrees of light. The contractile range therefore of the pupil is increased in these animals, so as 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 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.



[The figure represents the iris of a lion. B B, the straight or converging fibres; C, the fibres which encircle the inner margin of the iris.]

CHAPTER XIII.

PECULIAR ORGANISATIONS.

I BELIEVE that all the instances which I shall collect under this title might, consistently enough with technical language, have been placed under the head of *Comparative Anatomy*. But there appears to me an impropriety in the use which that term hath obtained; it being, in some sort, absurd to call that a case of comparative anatomy in which there is nothing to "compare;" in which a conformation is found in one animal, which hath nothing properly answering to it in another. Of this kind are the examples which I have to propose in the present chapter; and the reader will see that, though some of them be the strongest, perhaps, he will meet with under any division of our subject, they must necessarily be of an unconnected and miscellaneous nature. To dispose them, however, into some sort of order, we will notice, first, particularities of structure which belong to quadrupeds, birds, and fish, as such, or to many of the kinds included in these classes of animals; and then, such particularities as are confined to one or two species.

I. Along each side of the neck of large *quadrupeds* runs a stiff robust cartilage, which butchers call the paxwax. No person can carve the upper end of a crop of beef without driving his knife against it. It is a tough, strong, tendinous substance, braced from the head to the middle of the back: its office is to assist in supporting the weight of the head. It is a mechanical provision, of which this is the undisputed use; and it is sufficient, and not more than sufficient, for the purpose which it has to execute. The head of an ox or a horse is a heavy weight, acting at the end of a long lever (consequently

with a great purchase), and in a direction nearly perpendicular to the joints of the supporting neck. From such a force, so advantageously applied, the bones of the neck would be in constant danger of dislocation, if they were not fortified by this strong tape. No such organ is found in the human subject, because, from the erect position of the head (the pressure of it acting nearly in the direction of the spine), the junction of the vertebræ appears to be sufficiently secure without it. This cautionary expedient therefore is limited to quadrupeds: the care of the Creator is seen where it is wanted.[55]

II. The oil with which *birds* preen their feathers, and the organ which supplies it, is a specific provision for the winged creation. On each side of the rump of birds is observed a small nipple, yielding upon pressure a butter-like substance, which the bird extracts by pinching the pap with its bill. With this oil or ointment, thus procured, the bird dresses his coat; and repeats the action as often as its own sensations teach it that it is in any part wanted, or as the excretion may be sufficient for the expense. The gland, the pap, the nature and quality of the excreted substance, the manner of obtaining it from its lodgment in the body, the application of

[55] The author is not quite correct here, inasmuch as elastic ligaments are liberally supplied in the human spine: a range of peculiar ligaments, the "*ligamenta subflava*," run along the course of the spine, and are highly elastic. The *ligamentum nuchæ* is that ligament which runs from the prominence of the spine between the shoulders to the back of the head; and the student who hangs his head over his book enjoys the advantage of this elastic support: so that it is strictly a matter comparative; we may trace it with increasing strength from the ligament that sustains a man's head, to that which, like the spring of a steelyard, weighs against the immense head of the elephant.

These elastic ligaments vary with the length and motion of the neck. It would be tedious to describe their varieties in the camel, camelopard, ostrich, &c. We may be satisfied with the fact, that the elastic ligament is a structure extensively used in the animal textures, generally coming in aid of the muscles, or as a substitute for them.

it when obtained, form, collectively, an evidence of intention which it is not easy to withstand. Nothing similar to it is found in unfeathered animals. What blind *conatus* of nature should produce it in birds; should not produce it in beasts?

III. The air-bladder also of a *fish* affords a plain and direct instance, not only of contrivance, but strictly of that species of contrivance which we denominate mechanical. It is a philosophical apparatus in the body of an animal. The principle of the contrivance is clear: the application of the principle is also clear. The use of the organ to sustain, and, at will, also to elevate, the body of the fish in the water, is proved by observing, what has been tried, that, when the bladder is burst, the fish grovels at the bottom; and also, that flounders, soles, skates, which are without the air-bladder, seldom rise in the water, and that with effort. The manner in which the purpose is attained, and the suitableness of the means to the end, are not difficult to be apprehended. The rising and sinking of a fish in water, so far as it is independent of the stroke of the fins and tail, can only be regulated by the specific gravity of the body. When the bladder, contained in the body of the fish, is contracted, which the fish probably possesses a muscular power of doing, the bulk of the fish is contracted along with it; whereby, since the absolute weight remains the same, the specific gravity, which is the sinking force, is increased, and the fish descends: on the contrary, when, in consequence of the relaxation of the muscles, the elasticity of the enclosed and now compressed air restores the dimensions of the bladder, the tendency downwards becomes proportionably less than it was before, or is turned into a contrary tendency. These are known properties of bodies immersed in a fluid. The enamelled figures, or little glass bubbles, in a jar of water, are made to rise and fall by the same artifice. A diving-machine might be made to ascend and descend upon the like principle; namely, by introducing into the inside of it an air-vessel, which, by its contraction, would diminish, and by its distension enlarge the bulk of the machine itself,

and thus render it specifically heavier or specifically lighter than the water which surrounds it. Suppose this to be done, and the artist to solicit a patent for his invention: the inspectors of the model, whatever they might think of the use or value of the contrivance, could by no possibility entertain a question in their minds, whether it were a contrivance or not. No reason has ever been assigned,—no reason can be assigned, why the conclusion is not as certain in the fish as it is in the machine; why the argument is not as firm in one case as the other.

It would be very worthy of inquiry, if it were possible to discover, by what method an animal which lives constantly in water is able to supply a repository of air. The expedient, whatever it be, forms part, and perhaps the most curious part of the provision. Nothing similar to the air-bladder is found in land-animals; and a life in the water has no natural tendency to produce a bag of air. Nothing can be farther from an acquired organisation than this is.[56]

[56] The sea varies in temperature and pressure at different depths, and no doubt the texture of the fish, and especially of its integument, must conform to this variety. The swimming-bladder is the means of adjustment by which the fish lives at its native depths without waste of animal exertion: such is the power of expansion of the air-bladder when relieved from the pressure, that, when a fish is brought up from the greatest depth, it inverts and thrusts out the viscera from the mouth. We do not see, however, that naturalists have adverted to the place of this swimming-bladder. It lies close to the spine, and appears to counterbalance, in some measure at least, the air in the intestines by being thus placed above them. In the cetacea, as the whale, their buoyancy proceeds from the quantity of oil under the skin, especially of their head, and which it has been observed is bestowed in order to ensure their readily coming to the surface to breathe when their natural powers are weakened. For the same reason, that they may raise their heads to the surface, their tails are horizontal. In the jelly-fish, those soft animals which float in sheltered estuaries (the *physsophora*), there is an air-vessel which they can fill and empty,

These examples mark the attention of the Creator to the three great kingdoms of his animal creation, and to their constitution as such. The example which stands next in point of generality, belonging to a large tribe of animals, or rather to various species of that tribe, is the poisonous tooth of serpents.

I. The *fang of a viper* is a clear and curious example of mechanical contrivance. It is a perforated tooth, loose at the root: in its quiet state, lying down flat upon the jaw, but furnished with a muscle which, with a jerk, and by the pluck, as it were, of a string, suddenly erects it. Under the tooth, close to its root, and communicating with the perforation, lies a small bag containing the venom. When the fang is raised, the closing of the jaw presses its root against the bag underneath; and the force of this compression sends out the fluid with a considerable impetus through the tube in the middle of the tooth. What more unequivocal or effectual apparatus could be devised for the double purpose of at once inflicting the wound and injecting the poison? Yet, though lodged in the mouth, it is so constituted, as, in its inoffensive and quiescent state, not to interfere with the animal's ordinary office of receiving its food. It has been observed also, that none of the harmless serpents, the black snake, the blind worm, &c., have these fangs, but teeth of an equal size; not moveable as this is, but fixed into the jaw.

II. In being the property of several different species, the preceding example is resembled by that which I shall next mention, which is the *bag of the opossum.* This is a mechanical contrivance, most properly so called. The simplicity of the expedient renders the contrivance more obvious than many others, and by no means less certain. A false skin under the belly of the animal forms a pouch, into which the young litter are received at their birth; where they have an easy and constant access to the teats; in which they are transported by the

by which means they rise or sink at pleasure. Others (the *villela*) raise a sail. Some of this class propel themselves by taking in water, and suddenly rejecting it.

dam from place to place; where they are at liberty to run in and out; and where they find a refuge from surprise and danger. It is their cradle, their asylum, and the machine for their conveyance. Can the use of this structure be doubted of? Nor is it a mere doubling of the skin; but is a new organ, furnished with bones and muscles of its own. Two bones are placed before the os pubis, and joined to that bone as their base. These support and give a fixture to the muscles which serve to open the bag. To these muscles there are antagonists, which serve in the same manner to shut it; and this office they perform so exactly, that, in the living animal, the opening can scarcely be discerned, except when the sides are forcibly drawn asunder.* Is there any action in this part of the animal, any process arising from that action, by which these members could be formed? any account to be given of the formation, except design?

III. As a particularity, yet appertaining to more species than one, and also as strictly mechanical, we may notice a circumstance in the structure of the *claws* of certain birds. The middle claw of the heron and cormorant is toothed and notched like a saw. These birds are great fishers, and these notches assist them in holding their slippery prey. The use is evident; but the structure such as cannot at all be accounted for by the effort of the animal, or the exercise of the part. Some other fishing birds have these notches in their *bills;* and for the same purpose. The gannet, or Soland goose, has the side of its bill irregularly jagged, that it may hold its prey the faster. Nor can the structure in this, more than in the former case, arise from the manner of employing the part. The smooth surfaces, and soft flesh of fish, were less likely to notch the bills of birds, than the hard bodies upon which many other species feed.

We now come to particularities strictly so called, as being limited to a single species of animal. Of these I shall take one from a quadruped, and one from a bird.

I. The *stomach of the camel* is well known to retain

* Goldsmith, Nat. Hist., vol. iv. p. 244.

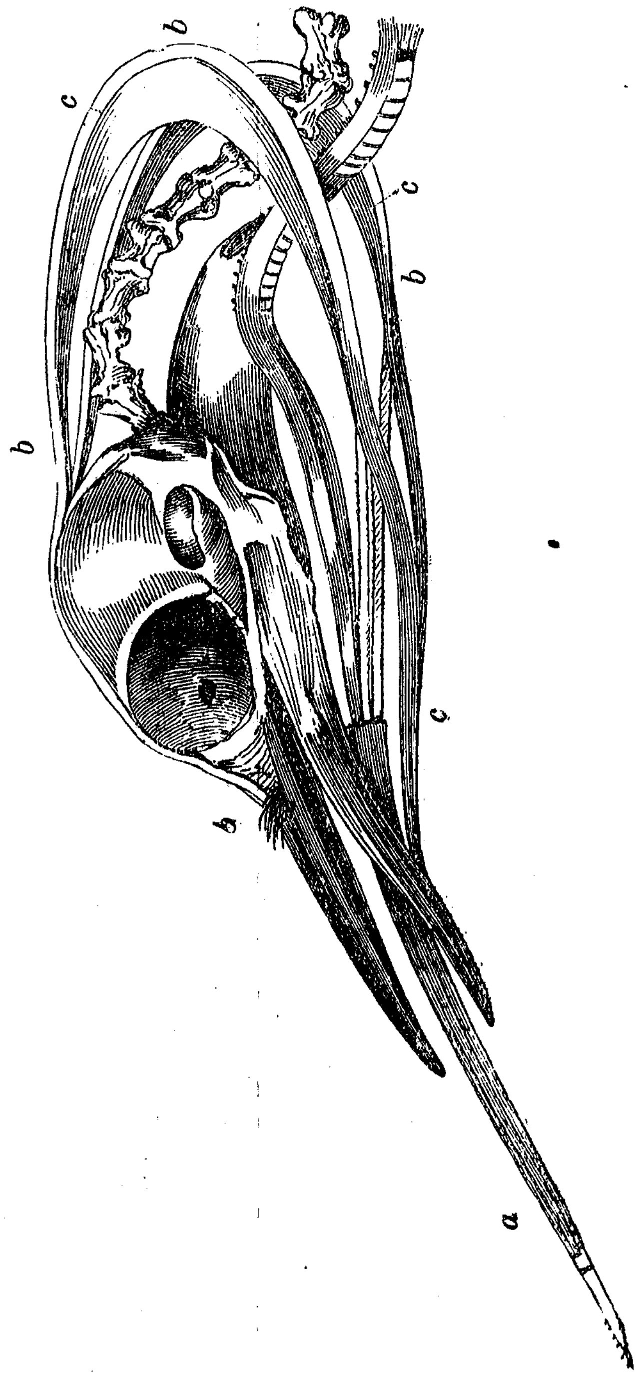
large quantities of water, and to retain it unchanged for a considerable length of time. This property qualifies it for living in the desert. Let us see, therefore, what is the internal organisation, upon which a faculty so rare and so beneficial depends. A number of distinct sacs or bags (in a dromedary thirty of these have been counted) are observed to lie between the membranes of the second stomach, and to open into the stomach near the top by small square apertures. Through these orifices, after the stomach is full, the annexed bags are filled from it: and the water so deposited is, in the first place, not liable to pass into the intestines; in the second place, is kept separate from the solid aliment; and, in the third place, is out of the reach of the digestive action of the stomach, or of mixture with the gastric juice. It appears probable, or rather certain, that the animal, by the conformation of its muscles, possesses the power of squeezing back this water from the adjacent bags into the stomach, whenever thirst excites it to put this power in action.

II. The *tongue of the woodpecker* is one of those singularities which nature presents us with when a singular purpose is to be answered. It is a particular instrument for a particular use; and what, except design, ever produces such? The woodpecker lives chiefly upon insects lodged in the bodies of decayed or decaying trees. For the purpose of boring into the wood, it is furnished with a bill straight, hard, angular, and sharp. When, by means of this piercer, it has reached the cells of the insects, then comes the office of its tongue: which tongue is, first, of such a length that the bird can dart it out three or four inches from the bill,—in this respect differing greatly from every other species of bird; in the second place, it is tipped with a stiff, sharp, bony thorn; and, in the third place (which appears to me the most remarkable property of all), this tip is dentated on both sides like the beard of an arrow or the barb of a hook. The description of the part declares its uses. The bird, having exposed the retreats of the insects by the assistance of its bill, with a motion inconceivably

quick, launches out at them this long tongue; transfixes them upon the barbed needle at the end of it; and thus draws its prey within its mouth. If this be not mechanism, what is? Should it be said, that, by continual endeavours to shoot out the tongue to the stretch, the woodpecker species may by degrees have lengthened the organ itself, beyond that of other birds, what account can be given of its form, of its tip? how, in particular, did it get its barb, its dentation? These barbs, in my opinion, wherever they occur, are decisive proofs of mechanical contrivance.[57]

[57] What could have tempted Buffon to express his pity for this bird as abject and degraded, it is not easy to conceive: nor why it should be described as leading an insipid life, because continually employed in boring and hammering the old stump of a tree. A late naturalist describes the woodpecker as enjoying the sweet hours of the morning, on the highest branch of the tallest tree, fluttering and playing with his mate and companions. No doubt his diligence, perseverance, and energy in plying his beak are very extraordinary. But, besides the wedge-like strength of the beak, and the power of the neck to strike with it, there is something remarkable in its sensibility. That nerve, the fifth pair, on which we have shown that all the sensibility of the head depends, transmits a large branch along the inside of the mandibles; and, as this nerve approaches the extremity, it perforates the bone by innumerable small canals, so as to be given to the horny covering of the beak, which is thus possessed of a sensibility to feel in the crevices of the wood, and under the bark; and the woodpecker is enabled by this means to direct the tongue, which our author correctly describes as moving with extraordinary celerity, and with a point like a barbed arrow.

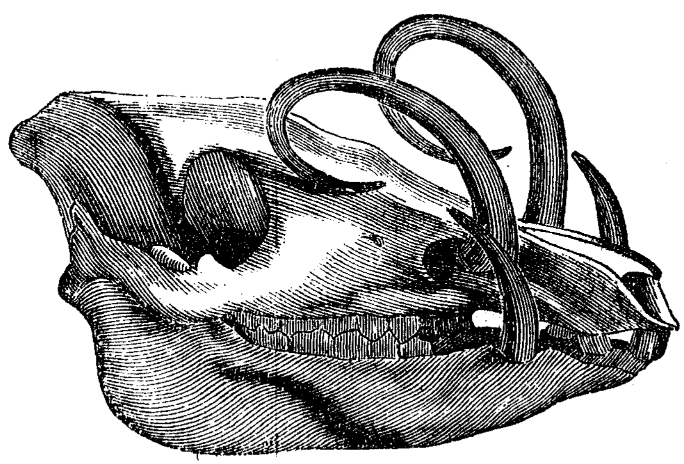
We have represented the dissection of the head of this bird more accurately in its anatomy than is to be found in books. We offer it because it exhibits a very curious piece of mechanism, adjusted to the tongue, to enable the animal to thrust it out far, and with unusual rapidity. *a* is the barbed tongue; *b*, two slender elastic ligamentous cartilages, of very peculiar structure and use. On one extremity they are attached to the bone which supports the upper mandible; from this we trace them over the skull down upon the sides



III. I shall add one more example, for the sake of its novelty. It is always an agreeable discovery, when,

of the neck; and, with a large sweep, turning under the lower mandible, and so continued into the tongue, and not terminating until they reach the horny point. *c c c*, a long muscle which follows these ligamentous cartilages upon their concave side, arising from the bone of the lower mandible, and so sweeping round with the cartilages and over the skull, to have another fixed point at the upper mandible: these protrude the tongue. Two muscles are seen to arise from the sides of the larynx, which are the opponents of the last, and retract the tongue. Leaving the other parts of the anatomy, we beg the reader's attention to the action of the muscle *c c c*, which presents one of those curious instances observed in comparative anatomy, of a mechanism adapted to a particular purpose. The tongue is not only thrust out far by this apparatus, but is shot with great rapidity, in correspondence with its barbed point. This effect is produced by the two extremities of the muscle being fixed points, and the fibres of the muscle itself running on the concave side of the cartilaginous bow, so as to form a smaller circle. We require no mathematical demonstration to prove that the tongue must be thrust out to a greater distance than the measure of contraction of the muscle. Let us tie the line of the fishing-rod to its slender top, and pull upon it at the butt: the motion of the top will be very extensive, even when only an inch of the line is drawn through the rings. This is a pretty accurate representation of what takes place by the contraction of this protruding muscle. We have noticed that the upper end of this arch is fixed, the whole motion must therefore be given to the loose extremity in the tongue; and we cannot but observe that this peculiar arch and muscular ring are adapted for the rapid protrusion of the tongue; whilst its retraction is produced by a common muscle, that is, a muscle running in a straight course.

Another curious part of this apparatus is, that a very large gland, which pours out a glutinous matter, is embraced and compressed by the action of the circular muscle. This viscid secretion bedewing the tongue furnishes an additional means for the bird to pick up insects, such as ants, without the necessity of sticking each with its arrow. Nothing can be more mechanical, or more happily adapted to its purpose, than the whole of this structure, and consequently nothing having remarked in an animal an extraordinary structure, we come at length to find out an unexpected use for it. The following narrative furnishes an instance of this kind. The babyroussa, or Indian hog, a species of wild boar, found in the East Indies, has two *bent* teeth, more than half a yard long, growing upwards, and (which is the singularity) from the upper jaw. These instruments are not wanted for offence; that service being provided for by two tusks issuing from the under jaw, and resembling those of the common boar: nor does the animal use them for defence. They might seem, therefore, to be both a superfluity and an encumbrance. But observe the event: the animal sleeps standing; and, in order to support its head, hooks its upper tusks upon the branches of trees.[58]



better suited to strengthen the argument in the text. Indeed it is not inferior to the means employed for giving rapidity of motion to the *membrana nictitans* of the eye of the bird.

58 This notion of the babyroussa sleeping on its feet and hanging by its teeth the while, is a mere fancy. It has arisen from the difficulty of accounting for the teeth, which rise out from the mouth, and turn up before the eyes. The better opinion is, that they guard the eyes in rushing through the thick underwood.

CHAPTER XIV.

PROSPECTIVE CONTRIVANCES.

I CAN hardly imagine to myself a more distinguishing mark, and, consequently, a more certain proof of design, than *preparation—i. e.*, the providing of things beforehand, which are not to be used until a considerable time afterwards: for this implies a contemplation of the future, which belongs only to intelligence.

Of these *prospective* contrivances, the bodies of animals furnish various examples.

I. The human teeth afford an instance, not only of prospective contrivance, but of the completion of the contrivance being designedly suspended. They are formed within the gums, and there they stop; the fact being, that their farther advance to maturity would not only be useless to the new-born animal, but extremely in its way; as it is evident that the act of *sucking*, by which it is for some time to be nourished, will be performed with more ease both to the nurse and to the infant, whilst the inside of the mouth and edges of the gums are smooth and soft, than if set with hard-pointed bones. By the time they are wanted the teeth are ready. They have been lodged within the gums for some months past, but detained, as it were, in their sockets, so long as their farther protrusion would interfere with the office to which the mouth is destined. Nature, namely, that intelligence which was employed in creation, looked beyond the first year of the infant's life; yet, whilst she was providing for functions which were after that term to become necessary, was careful not to incommode those which preceded them. What renders it more probable that this is the effect of design, is, that the teeth are imperfect, whilst all other parts of the mouth are perfect. The lips are perfect, the tongue is perfect; the cheeks, the jaws, the palate, the pharynx, the larynx, are all perfect: the teeth alone are not so. This is the fact with respect to the human mouth: the fact also is, that the parts above enumerated are called into use from the beginning; whereas the teeth would be only so many obstacles and annoyances, if they were there. When a contrary order is necessary, a contrary order prevails. In the worm of the beetle, as hatched from the egg, the teeth are the first things which arrive at perfection. The insect begins to gnaw as soon as it escapes from the shell, though its other parts be only gradually advancing to their maturity.[59]

What has been observed of the teeth, is true of the *horns* of animals; and for the same reason. The horn of a calf or a lamb does not bud, or at least does not sprout to any considerable length, until the animal be capable of browsing upon its pasture; because such a substance upon the forehead of the young animal would very much incommode the teat of the dam in the office of giving suck.

But in the case of the *teeth*—of the human teeth at least, the prospective contrivance looks still farther. A succession of crops is provided, and provided from the beginning; a second tier being originally formed beneath the first, which do not come into use till several years afterwards. And this double or suppletory provision meets a difficulty in the mechanism of the mouth, which would have appeared almost insurmountable. The expansion of the jaw (the consequence of the proportionable growth of the animal, and of its skull) necessarily separates the teeth of the first set, however compactly disposed, to a distance from one another, which would be very inconvenient. In due time, therefore, *i. e.*, when the jaw has attained a great part of its dimensions, a new set of teeth springs up (loosening and pushing out the old ones before them), more exactly fitted to the space which they are to occupy, and rising also in such

[59] See the note upon the teeth in the Appendix. The subject is full of interest.

close ranks, as to allow for any extension of line which the subsequent enlargement of the head may occasion.[60]

II. It is not very easy to conceive a more evidently prospective contrivance than that which, in all viviparous animals, is found in the *milk* of the female parent. At the moment the young animal enters the world there is its maintenance ready for it. The particulars to be remarked in this economy are neither few nor slight. We have, first, the nutritious quality of the fluid, unlike, in this respect, every other excretion of the body; and in which nature hitherto remains unimitated, neither cookery nor chemistry having been able to make milk out of grass: we have, secondly, the organ for its reception and retention: we have, thirdly, the excretory duct annexed to that organ: and we have, lastly, the determination of the milk to the breast at the particular juncture when it is about to be wanted. We have all these properties in the subject before us; and they are all indications of design. The last circumstance is the strongest of any. If I had been to guess beforehand, I should have conjectured, that at the time when there was an extraordinary demand for nourishment in one part of the system there would be the least likelihood of a redundancy to supply another part. The advanced pregnancy of the female has no intelligible tendency to fill the breasts with milk. The lacteal system is a constant wonder; and it adds to other causes of our admiration, that the number of the teats or paps in each species is found to bear a proportion to the number of the young. In the sow, the bitch, the rabbit, the cat,

[60] The second or permanent set of teeth does not push out the deciduous or milk teeth. The process is not mechanical. Whilst yet a tender membrane is around the second tooth, those of the first set are suffering absorption at their fangs. Another circumstance, which shows the provision not to be mechanical, is the wasting of the old alveolar process, and the growth of the new: the new alveolar process or socket of the permanent tooth is forming at the time that the portion of the jaw which held the first tooth firm is yielding by absorption.

the rat, which have numerous litters, the paps are numerous, and are disposed along the whole length of the belly: in the cow and mare, they are few. The most simple account of this, is to refer it to a designing Creator.[61]

But in the argument before us, we are entitled to consider not only animal bodies when framed, but the circumstance under which they are framed: and in this view of the subject, the constitution of many of their parts is most strictly prospective.

III. The eye is of no use, at the time when it is formed. It is an optical instrument made in a dungeon; constructed for the refraction of light to a focus, and perfect for its purpose, before a ray of light has had access to it; geometrically adapted to the properties and action of an element with which it has no communication. It is about indeed to enter into that communication: and this is precisely the thing which evidences intention. It is *providing* for the *future* in the closest sense which can be given to these terms; for it is providing for a future change; not for the then subsisting condition of the animal; not for any gradual progress or advance in that same condition; but for a new state, the consequence of a great and sudden alteration, which the animal is to undergo at its birth. Is it to be believed that the eye was formed, or, which is the same thing, that the series of causes was fixed by which the eye is formed, without a view to this change; without a prospect of that condition, in which its fabric, of no use at present, is about to be of the greatest; without a consideration of the qualities of that element, hitherto entirely excluded, but with which it was hereafter to hold so intimate a relation? A young man makes a pair of spectacles for himself against he grows old; for which spectacles he has no want or use whatever at the time he makes them. Could this be done without knowing and considering the defect of vision to which advanced age is subject? Would not the precise suitableness of the instrument to its purpose, of the remedy to the defect, of the convex lens to the flattened eye, establish the certainty of the conclusion, that the case, afterwards to arise, had been considered beforehand, speculated upon, provided for? all which are exclusively the acts of a reasoning mind. The eye formed in one state, for use only in another state, and in a different state, affords a proof no less clear of destination to a future purpose; and a proof proportionably stronger, as the machinery is more complicated, and the adaptation more exact.

IV. What has been said of the eye, holds equally true of the lungs. Composed of air-vessels, where there is no air; elaborately constructed for the alternate admission and expulsion of an elastic fluid, where no such fluid exists; this great organ, with the whole apparatus belonging to it, lies collapsed in the fœtal thorax; yet in order, and in readiness for action, the first moment that the occasion requires its service. This is having a machine locked up in store for future use; which incontestably proves, that the case was expected to occur in which this use might be experienced; but expectation is the proper act of intelligence. Considering the state

[61] The only parallel to this is the care with which nature secures the nourishment of the embryon plant, or the chick in the egg. The lobes of a bean or a pea, and of most seeds, consist of a deposit of nutritious matter, and when heat and moisture favour the development of the living property, vessels which are scattered in these lobes or cotyledons commence absorption of the matter, and carry it to the centre of the plant. It is remarkable that these lobes, having thus, in the first instance, supplied the young plant with nutritious matter, change their office, and, rising above the surface, become the first leaves. Thus we see how the nourishment is supplied, until the radicle is pushed down into the earth, and the leaves receive the influence of the atmosphere. So in the chick, the white or albumen of the egg goes to its nourishment whilst it is in the shell: but the yolk of the egg is embraced in the body of the chick when excluded from the shell, and a duct leads from the membrane enclosing this mass of nutriment into the first intestine. And thus is the chick nourished, not only whilst included in the shell, but also during its first feeble existence, a period which corresponds with that of lactation in mammalia.

in which an animal exists before its birth, I should look for nothing less in its body than a system of lungs. It is like finding a pair of bellows in the bottom of the sea; of no sort of use in the situation in which they are found; formed for an action which was impossible to be exerted; holding no relation or fitness to the element which surrounds them, but both to another element in another place.

As part and parcel of the same plan ought to be mentioned, in speaking of the lungs, the provisionary contrivances of the *foramen ovale* and *ductus arteriosus*. In the fœtus pipes are laid for the passage of the blood through the lungs; but, until the lungs be inflated by the inspiration of air, that passage is impervious, or in a great degree obstructed. What then is to be done? What would an artist, what would a master, do upon the occasion? He would endeavour, most probably, to provide a *temporary* passage, which might carry on the communication required, until the other was open. Now this is the thing which is actually done in the heart. Instead of the circuitous route through the lungs which the blood afterwards takes before it get from one auricle of the heart to the other, a portion of the blood passes immediately from the right auricle to the left, through a hole placed in the partition which separates these cavities. This hole anatomists call the *foramen ovale*. There is likewise another cross cut, answering the same purpose, by what is called the *ductus arteriosus*, lying between the pulmonary artery and the aörta. But both expedients are so strictly temporary, that after birth the one passage is closed, and the tube which forms the other shrivelled up into a ligament. If this be not contrivance, what is?

But, forasmuch as the action of the air upon the blood in the lungs appears to be necessary to the perfect concoction of that fluid, *i. e.*, to the life and health of the animal (otherwise the shortest route might still be the best), how comes it to pass that the *fœtus* lives, and grows, and thrives without it? The answer is, that the blood of the fœtus is the mother's; that it has under-

gone that action in her habit; that one pair of lungs serves for both. When the animals are separated a new necessity arises; and to meet this necessity as soon as it occurs an organisation is prepared. It is ready for its purpose; it only waits for the atmosphere; it begins to play the moment the air is admitted to it.[62]

[62] Does not the whole condition of the embryon go to this argument? At first there is a mere jelly, or what appears as such; a little further advanced, and there are bones, and muscles, and nerves. But these lie quite inactive for a long term; the nerve excites to no action; the muscles do not move; the joints are not exercised, they are perfected slowly. The period of full development is not arrived; they have not yet their stimulus to activity. The whole then is in a state of preparation. Conduit pipes without their fluids, glands and ducts without their secretions, sensibilities dormant, and a mechanism quite inoperative; a whole animal system beautifully contrived, but only in "prospective contrivance."

CHAPTER XV.

RELATIONS.

When several different parts contribute to one effect, or, which is the same thing, when an effect is produced by the joint action of different instruments; the fitness of such parts or instruments to one another for the purpose of producing, by their united action, the effect, is what I call *relation;* and wherever this is observed in the works of nature or of man it appears to me to carry along with it decisive evidence of understanding, intention, art. In examining, for instance, the several parts of a *watch*, the spring, the barrel, the chain, the fusee, the balance, the wheels of various sizes, forms, and positions, what is it which would take an observer's attention, as most plainly evincing a construction, directed by thought, deliberation, and contrivance? It is the suitableness of these parts to one another; first, in the succession and order in which they act; and, secondly, with a view to the effect finally produced. Thus, referring the spring to the wheels, our observer sees in it that which originates and upholds *their* motion; in the chain, that which transmits the motion to the fusee; in the fusee, that which communicates it to the wheels; in the conical figure of the fusee, if he refer to the spring, he sees that which corrects the inequality of its force. Referring the wheels to one another, he notices, first, their teeth, which would have been without use or meaning if there had been only one wheel, or if the wheels had had no connexion between themselves, or common bearing upon some joint effect; secondly, the correspondency of their position, so that the teeth of one wheel catch into the teeth of another; thirdly, the proportion observed in the number of teeth in each wheel, which determines the rate of going. Referring the balance to the rest of the works, he saw, when he came to understand its action, that which rendered their motions equable. Lastly, in looking upon the index and face of the watch, he saw the use and conclusion of the mechanism, viz., marking the succession of minutes and hours; but all depending upon the motions within, all upon the system of intermediate actions between the spring and the pointer. What thus struck his attention in the several parts of the watch he might probably designate by one general name of "relation;" and observing with respect to all cases whatever, in which the origin and formation of a thing could be ascertained by evidence, that these relations were found in things produced by art and design, and in no other things, he would rightly deem of them as characteristic of such productions. To apply the reasoning here described to the works of nature.

The animal economy is full, is made up, of these *relations.*

I. There are, first, what in one form or other belong to all animals, the parts and powers which successively act upon their *food.* Compare this action with the process of a manufactory. In men and quadrupeds the aliment is first broken and bruised by mechanical instruments of mastication, viz., sharp spikes or hard knobs, pressing against or rubbing upon one another; thus ground and comminuted, it is carried by a pipe into the stomach, where it waits to undergo a great chemical action, which we call digestion: when digested it is delivered through an orifice, which opens and shuts, as there is occasion, into the first intestine; there, after being mixed with certain proper ingredients, poured through a hole in the side of the vessel, it is farther dissolved: in this state the milk, chyle, or part which is wanted, and which is suited for animal nourishment, is strained off by the mouths of very small tubes opening into the cavity of the intestines; thus freed from its grosser parts, the percolated fluid is carried by a long, winding, but traceable course, into the main stream of the old circulation; which conveys it in its progress to every part of the body. Now I say again, compare this with the process of a manufactory, with the making of cider, for example; with the bruising of the apples in the mill, the squeezing of them when so bruised in the press, the fermentation in the vat, the bestowing of the liquor thus fermented in the hogsheads, the drawing off into bottles, the pouring out for use into the glass. Let any one show me any difference between these two cases as to the point of contrivance. That which is at present under our consideration, the "relation" of the parts successively employed, is not more clear in the last case than in the first. The aptness of the jaws and teeth to prepare the food for the stomach is, at least, as manifest as that of the cider-mill to crush the apples for the press. The concoction of the food in the stomach is as necessary for its future use as the fermentation of the stum in the vat is to the perfection of the liquor. The disposal of the aliment afterwards, the action and change which it undergoes, the route which it is made to take, in order that, and until that, it arrive at its destination, is more complex indeed and intricate, but, in the midst of complication and intricacy, as evident and certain as is the apparatus of cocks, pipes, tunnels, for transferring the cider from one vessel to another; of barrels and bottles for preserving it till fit for use, or of cups and glasses for bringing it when wanted to the lip of the consumer. The character of the machinery is in both cases this,—that one part answers to another part, and every part to the final result.

This parallel between the alimentary operation and some of the processes of art might be carried further into detail. Spallanzani has remarked* a circumstantial resemblance between the stomachs of gallinaceous fowls and the structure of *corn-mills*. Whilst the two sides of the gizzard perform the office of the mill-stones, the craw or crop supplies the place of the *hopper*.

When our fowls are abundantly supplied with meat, they soon fill their craw; but it does not immediately pass thence into the gizzard; it always enters in very small quantities, in proportion to the progress of trituration, in like manner as, in a mill, a receiver is fixed above the two large stones which serve for grinding the

* Disc. i. sec. liv.

corn, which receiver, although the corn be put into it in bushels, allows the grain to dribble only in small quantities into the central hole in the upper mill-stone.

But we have not done with the alimentary history. There subsists a general *relation* between the external organs of an animal by which it procures its food and the internal powers by which it digests it. Birds of prey, by their talons and beaks, are qualified to seize and devour many species both of other birds and of quadrupeds. The constitution of the stomach agrees exactly with the form of the members. The gastric juice of a bird of prey, of an owl, a falcon, or a kite, acts upon the animal fibre alone; it will not act upon seeds or grasses at all. On the other hand, the conformation of the mouth of the sheep or the ox is suited for browsing upon herbage. Nothing about these animals is fitted for the pursuit of living prey. Accordingly it has been found by experiments, tried not many years ago, with perforated balls, that the gastric juice of ruminating animals, such as the sheep and the ox, speedily dissolves vegetables, but makes no impression upon animal bodies. This accordancy is still more particular. The gastric juice, even of granivorous birds, will not act upon the grain whilst whole and entire. In performing the experiment of digesting with the gastric juice in vessels, the grain must be crushed and bruised before it be submitted to the menstruum, that is to say, must undergo by art, without the body, the preparatory action which the gizzard exerts upon it within the body, or no digestion will take place. So strict, in this case, is the relation between the offices assigned to the digestive organ, between the mechanical operation and the chemical process.

II. The relation of the kidneys to the bladder, and of the ureters to both, *i. e.*, of the secreting organ to the vessel receiving the secreted liquor, and the pipe laid from one to the other for the purpose of conveying it from one to the other, is as manifest as it is amongst the different vessels employed in a distillery, or in the communications between them. The animal structure, in this case, being simple, and the parts easily separated, it forms an instance of correlation which may be presented by dissection to every eye, or which, indeed, without dissection, is capable of being apprehended by every understanding. This correlation of instruments to one another fixes intention somewhere—especially when every other solution is negatived by the conformation. If the bladder had been merely an expansion of the ureter, produced by retention of the fluid, there ought to have been a bladder for each ureter. One receptacle fed by two pipes issuing from different sides of the body, yet from both conveying the same fluid, is not to be accounted for by any such supposition as this.

III. Relation of parts to one another accompanies us throughout the whole animal economy. Can any relation be more simple, yet more convincing than this, that the eyes are so placed as to look in the direction in which the legs move and the hands work? It might have happened very differently if it had been left to chance. There were at least three-quarters of the compass out of four to have erred in. Any considerable alteration in the position of the eye or the figure of the joints would have disturbed the line, and destroyed the alliance between the sense and the limbs.

IV. But relation, perhaps, is never so striking as when it subsists, not between different parts of the same thing, but between different things. The relation between a lock and a key is more obvious than it is between different parts of the lock. A bow was designed for an arrow, and an arrow for a bow; and the design is more evident for their being separate implements.

Nor do the works of the Deity want this clearest species of relation. The *sexes* are manifestly made for each other. They form the grand relation of animated nature, universal, organic, mechanical, subsisting, like the clearest relations of art, in different individuals, unequivocal, inexplicable without design.

So much so, that, were every other proof of contrivance in nature dubious or obscure, this alone would be sufficient. The example is complete. Nothing is wanting to the argument. I see no way whatever of getting over it.

V. The teats of animals which give suck bear a relation to the mouth of the suckling progeny, particularly to the lips and tongue. Here also, as before, is a correspondency of parts, which parts subsist in different individuals.

These are *general* relations, or the relations of parts which are found either in all animals or in large classes and descriptions of animals. *Particular* relations, or the relations which subsist between the particular configuration of one or more parts of certain species of animals, and the particular configuration of one or more other parts of the same animal (which is the sort of relation that is, perhaps, most striking), are such as the following:—

I. In the *swan*, the web-foot, the spoon-bill, the long neck, the thick down, the graminivorous stomach, bear all a relation to one another, inasmuch as they all concur in one design, that of supplying the occasions of an aquatic fowl floating upon the surface of shallow pools of water, and seeking its food at the bottom. Begin with any one of these particularities of structure, and observe how the rest follow it. The web-foot qualifies the bird for swimming; the spoon-bill enables it to graze. But how is an animal floating upon the surface of pools of water to graze at the bottom, except by the mediation of a long neck? A long neck accordingly is given to it. Again, a warm-blooded animal which was to pass its life upon water, required a defence against the coldness of that element. Such a defence is furnished to the swan in the muff in which its body is wrapped. But all this outward apparatus would have been in vain, if the intestinal system had not been suited to the digestion of vegetable substances. I say suited to the digestion of vegetable substances; for it is well known that there are two intestinal systems found in birds: one with a membranous stomach and a gastric juice, capable of dissolving animal substances alone—the other with a crop and gizzard calculated for the moistening, bruising, and afterwards digesting, of vegetable aliment.

Or set off with any other distinctive part in the body of the swan; for instance, with the long neck. The long neck, without the web-foot, would have been an encumbrance to the bird; yet there is no necessary connexion between a long neck and a web-foot. In fact they do not usually go together. How happens it, therefore, that they meet only when a particular design demands the aid of both?

II. This mutual relation, arising from a subserviency to a common purpose, is very observable also in the parts of a *mole*. The strong short legs of that animal, the palmated feet, armed with sharp nails, the pig-like nose, the teeth, the velvet coat, the small external ear, the sagacious smell, the sunk protected eye, all conduce to the utilities or to the safety of its under-ground life. It is a special purpose, specially consulted throughout. The form of the feet fixes the character of the animal. They are so many shovels; they determine its action to that of rooting in the ground; and everything about its body agrees with this destination. The cylindrical figure of the mole, as well as the compactness of its form, arising from the terseness of its limbs, proportionably lessens its labour; because, according to its bulk, it thereby requires the least possible quantity of earth to be removed for its progress. It has nearly the same structure of the face and jaws as a swine, and the same office for them. The nose is sharp, slender, tendinous, strong, with a pair of nerves going down to the end of it. The plush covering which, by the smoothness, closeness, and polish of the short piles that compose it, rejects the adhesion of almost every species of earth, defends the animal from cold and wet, and from the impediment which it would experience by the mould sticking to its body. From soils of all kinds the little pioneer comes forth bright and clean. Inhabiting dirt, it is of all animals the neatest.

But what I have always most admired in the mole is its *eyes*. This animal occasionally visiting the surface, and wanting, for its safety and direction, to be informed when it does so, or when it approaches it, a perception of light was necessary. I do not know that the clearness of sight depends at all upon the size of the organ. What is gained by the largeness or prominence of the globe of the eye, is width in the field of vision. Such a capacity would be of no use to an animal which was to seek its food in the dark. The mole did not want to look about it; nor would a large advanced eye have been easily defended from the annoyance to which the life of the animal must constantly expose it. How indeed was the mole, working its way under ground, to guard its eyes at all? In order to meet this difficulty, the eyes are made scarcely larger than the head of a corking-pin; and these minute globules are sunk so deeply in the skull, and lie so sheltered within the velvet of its covering, as that any contraction of what may be called the eye-brows, not only closes up the apertures which lead to the eyes, but presents a cushion, as it were, to any sharp or protruding substance which might push against them. This aperture, even in its ordinary state, is like a pin-hole in a piece of velvet, scarcely pervious to loose particles of earth.

Observe, then, in this structure, that which we call relation. There is no natural connexion between a small sunk eye and a shovel palmated foot. Palmated feet might have been joined with goggle eyes; or small eyes might have been joined with feet of any other form. What was it therefore which brought them together in the mole? That which brought together the barrel, the chain, and the fusee in a watch—design; and design in both cases inferred, from the relation which the parts bear to one another in the prosecution of a common purpose. As hath already been observed, there are different ways of stating the relation, according as we set out from a different part. In the instance before us, we may either consider the shape of the feet, as qualifying the animal for that mode of life and inhabitation to which the structure of its eyes confines it; or we may consider the structure of the eye as the only one which would have suited with the action to which the feet are adapted. The relation is manifest, whichever of the parts related we place first in the order of our consideration. In a word, the feet of the mole are made for digging: the neck, nose, eyes, ears, and skin, are peculiarly adapted to an underground life; and this is what I call relation.

CHAPTER XVI.

COMPENSATION.

Compensation is a species of relation. It is relation when the *defects* of one part, or of one organ, are supplied by the structure of another part, or of another organ. Thus—

I. The short unbending neck of the *elephant* is compensated by the length and flexibility of his *proboscis*. He could not have reached the ground without it; or, if it be supposed that he might have fed upon the fruit, leaves, or branches of trees, how was he to drink? Should it be asked, why is the elephant's neck so short? it may be answered, that the weight of a head so heavy could not have been supported at the end of a longer lever. To a form, therefore, in some respects necessary, but in some respects also inadequate to the occasion of the animal, a supplement is added, which exactly makes up the deficiency under which he laboured.

If it be suggested that this proboscis may have been produced, in a long course of generations, by the constant endeavour of the elephant to thrust out its nose (which is the general hypothesis by which it has lately been attempted to account for the forms of animated nature), I would ask, How was the animal to subsist in the mean time—during the process—*until* this prolongation of snout were completed? What was to become of the individual whilst the species was perfecting?[63]

[63] Whilst we have before us the daily proof of the capacities of animals for domestication, in considering their structure and their instincts, we must look back into that long period before man's creation, when they had not his protection and care. A thousand concurring testimonies

Our business at present is, simply to point out the relation which this organ bears to the peculiar figure of the animal to which it belongs. And herein all things correspond. The necessity of the elephant's proboscis arises from the shortness of his neck: the shortness of the neck is rendered necessary by the weight of the head. Were we to enter into an examination of the structure and anatomy of the proboscis itself, we should see in it one of the most curious of all examples of animal mechanism. The disposition of the ringlets and fibres, for the purpose, first, of forming a long cartilaginous pipe; secondly, of contracting and lengthening that pipe; thirdly, of turning it in every direction at the will of the animal; with the superaddition at the end,

prove that there were periods when the earth's surface was more suitable for brutes than it was for the abode of man; and when they were grouped together, each species with its enemy, and each with a power of preservation, at once to prevent too great an increase and total extermination. The young horse, which in his paddock has neither known bad treatment nor an enemy, will yet shiver and start away from a brindled swine, or any animal that is bristled or rough.

Geological researches, so happily combined with comparative anatomy, give us no room to conjecture that there has been anything like a progressive improvement in the species of animals. They have been created with all the characters in which they are now propagated; and had it been otherwise, the species would have become extinct, or they would have lost their place in that balance of offence and defence by which it has pleased the Creator to provide for their continuance.

One would imagine that an idea so wild, as that an animal should produce the variety of organs or external instruments which we see, by an effort—an energy proceeding from itself, could never have been maintained in an age like the present, when it is so fully proved that there is no change upon the extremity of an animal, no additional organ like this of the trunk of an elephant, no variety in its paw or its hoof, but what is attended with a corresponding alteration in the whole system of the creature—of its bones, its teeth, its stomach, as well as in its appetites and desires.

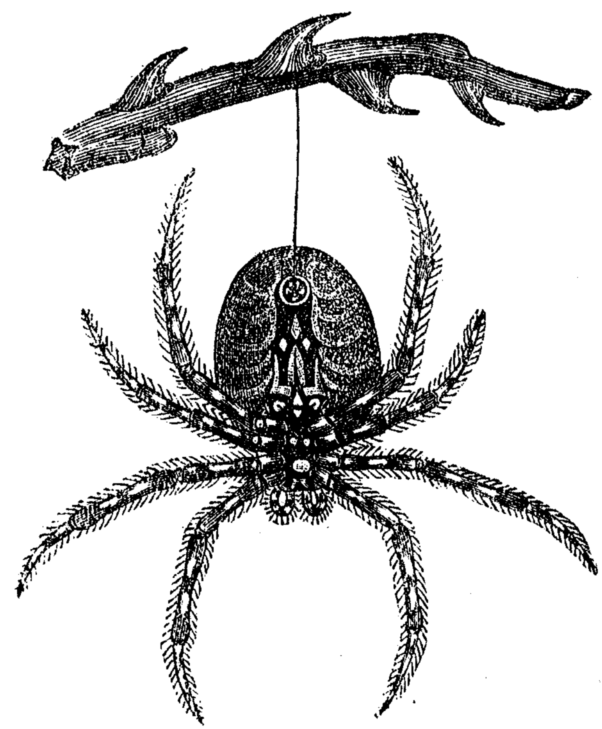
of a fleshy production, of about the length and thickness of a finger, and performing the office of a finger, so as to pick up a straw from the ground. These properties of the same organ, taken together, exhibit a specimen, not only of design (which is attested by the advantage), but of consummate art, and, as I may say, of elaborate preparation, in accomplishing that design.

II. The hook in the wing of a *bat* is strictly a mechanical, and, also, a *compensating* contrivance. At the angle of its wing there is a bent claw, exactly in the form of a hook, by which the bat attaches itself to the sides of rocks, caves, and buildings, laying hold of crevices, joinings, chinks, and roughnesses. It hooks itself by this claw; remains suspended by this hold; takes its flight from this position: which operations compensate for the decrepitude of its legs and feet. Without her hook, the bat would be the most helpless of all animals. She can neither run upon her feet, nor raise herself from the ground. These inabilities are made up to her by the contrivance in her wing; and in placing a claw on that part, the Creator has deviated from the analogy observed in winged animals. A singular defect required a singular substitute.

III. The *crane*-kind are to live and seek their food amongst the waters; yet, having no web-foot, are incapable of swimming. To make up for this deficiency, they are furnished with long legs for wading, or long bills for groping, or usually with both. This is *compensation*. But I think the true reflection upon the present instance is, how every part of nature is tenanted by appropriate inhabitants. Not only is the surface of deep waters peopled by numerous tribes of birds that swim, but marshes and shallow pools are furnished with hardly less numerous tribes of birds that wade.

IV. The common *parrot* has, in the structure of its beak, both an inconveniency and a *compensation* for it. When I speak of an inconveniency I have a view to a dilemma which frequently occurs in the works of nature —viz., that the peculiarity of structure by which an organ is made to answer one purpose necessarily unfits

it for some other purpose. This is the case before us. The upper bill of the parrot is so much hooked, and so much overlaps the lower, that if, as in other birds, the lower chap alone had motion, the bird could scarcely gape wide enough to receive its food: yet this hook and overlapping of the bill could not be spared, for it forms the very instrument by which the bird climbs,—to say nothing of the use which it makes of it in breaking nuts and the hard substances upon which it feeds. How, therefore, has nature provided for the opening of this occluded mouth? By making the upper chap moveable, as well as the lower. In most birds, the upper chap is connected, and makes but one piece, with the skull; but in the parrot the upper chap is joined to the bone of the head by a strong membrane placed on each side of it, which lifts and depresses it at pleasure.*



* Goldsmith's Nat. Hist., vol. v. p. 274.

V. The *spider's web* is a *compensating* contrivance. The spider lives upon flies, without wings to pursue them,—a case, one would have thought, of great difficulty, yet provided for, and provided for by a resource which no stratagem, no effort of the animal, could have produced, had not both its external and internal structure been specifically adapted to the operation.[64]

[64] There are few things better suited to remove the disgust into which young people are betrayed on the view of some natural objects, than this of the spider. They will find that the most despised creature may become a subject of admiration, and be selected by the naturalist to exhibit the marvellous works of the creation. The terms given to these insects lead us to expect interesting particulars concerning them, since they have been divided into vagrants, hunters, swimmers, and water-spiders, sedentary, and mason-spiders; thus evincing a variety in their condition, activity, and mode of life; and we cannot be surprised to find them varying in the performance of their vital functions (as, for example, in their mode of breathing), as well as in their extremities and instruments. Of these instruments the most striking is the apparatus for spinning and weaving, by which they not only fabricate webs to entangle their prey, but form cells for their residence and concealment; sometimes living in the ground, sometimes under water, yet breathing the atmosphere. Corresponding with their very singular organization are their instincts. We are familiar with the watchfulness and voracity of some spiders, when their prey is indicated by the vibration of the cords of their net-work. Others have the eye and disposition of the lynx or tiger, and after couching in concealment, leap upon their victims. Some conceal themselves under a silken hood or tube, six eyes only projecting. Some bore a hole in the earth, and line it as finely as if it were done with the trowel and mortar, and then hang it with delicate curtains. A very extraordinary degree of contrivance is exhibited in the trap-door spider. This door, from which it derives its name, has a frame and hinge on the mouth of the cell, and is so provided that the claw of the spider can lay hold of it, and whether she enters or goes out, says Mr. Kirby, the door shuts of itself. But the water-spider has a domicile more curious still: it is under water, with an opening at the lower part for her exit

VI. In many species of insects the eye is fixed, and consequently without the power of turning the pupil to the object. This great defect is, however, perfectly *compensated*, and by a mechanism which we should not suspect. The eye is a multiplying-glass with a lens looking in every direction and catching every object. By which means, although the orb of the eye be stationary, the field of vision is as ample as that of other animals, and is commanded on every side. When this lattice-work was first observed, the multiplicity and minuteness of the surfaces must have added to the surprise of the discovery. Adams tells us that fourteen hundred of these reticulations have been counted in the two eyes of a drone-bee.

In other cases the *compensation* is effected by the

and entrance; and although this cell be under water, it contains air like a diving-bell, so that the spider breathes the atmosphere. The air is renewed in the cell in a manner not easily explained. The spider comes to the surface; a bubble of air is attracted to its body; with this air she descends, and gets under her cell, when the air is disengaged and rises into the cell; and thus, though under water, she lives in the air. There must be some peculiar property of the surface of this creature by which she can move in the water surrounded with an atmosphere, and live under the water breathing the air.

The chief instrument by which the spider performs these wonders is the spinning apparatus. The matter from which the threads are spun is a liquid contained in cells; the ducts from these cells open upon little projecting teats, and the atmosphere has so immediate an effect upon this liquid, that upon exposure to it, the secretion becomes a tough and strong thread. Twenty-four of these fine strands form together a thread of the thickness of that of the silk-worm. We are assured that there are three different sorts of material thus produced, which are indeed required for the various purposes to which they are applied—as, for example, to mix up with the earth to form the cells,—to line these cells as with fine cotton,—to make light and floating threads by which they may be conveyed through the air, as well as those meshes which are so geometrically and correctly formed to entrap their prey.

number and position of the eyes themselves. The spider has eight eyes, mounted upon different parts of the head; two in front, two in the top of the head, two on each side. These eyes are without motion, but, by their situation, suited to comprehend every view which the wants or safety of the animal rendered it necessary for it to take.

VII. The Memoirs for the Natural History of Animals, published by the French Academy, A.D. 1687, furnish us with some curious particulars in the eye of a cameleon. Instead of two eyelids, it is covered by an eyelid with a hole in it. This singular structure appears to be *compensatory*, and to answer to some other singularities in the shape of the animal. The neck of the cameleon is inflexible. To make up for this, the eye is so prominent as that more than half of the ball stands out of the head, by means of which extraordinary projection the pupil of the eye can be carried by the muscles in every direction, and is capable of being pointed towards every object. But then, so unusual an exposure of the globe of the eye requires for its lubricity and defence a more than ordinary protection of eyelid, as well as a more than ordinary supply of moisture; yet the motion of an eyelid, formed according to the common construction, would be impeded, as it should seem, by the convexity of the organ. The aperture in the lid meets this difficulty. It enables the animal to keep the principal part of the surface of the eye under cover, and to preserve it in a due state of humidity without shutting out the light, or without performing every moment a nictitation which it is probable would be more laborious to this animal than to others.

VIII. In another animal, and in another part of the animal economy, the same Memoirs describe a most remarkable *substitution*. The reader will remember what we have already observed concerning the *intestinal* canal—that its length, so many times exceeding that of the body, promotes the extraction of the chyle from the aliment by giving room for the lacteal vessels to act upon it through a greater space. This long intestine, wher-

ever it occurs, is in other animals disposed in the abdomen from side to side in returning folds. But in the animal now under our notice the matter is managed otherwise. The same intention is mechanically effectuated, but by a mechanism of a different kind. The animal of which I speak is an amphibious quadruped, which our authors call the alopecias or sea-fox. The intestine is straight from one end to the other; but in this straight and consequently short intestine is a winding, corkscrew, spiral passage, through which the food, not without several circumvolutions, and in fact by a long route, is conducted to its exit. Here the shortness of the gut is *compensated* by the obliquity of the perforation.

IX. But the works of the Deity are known by expedients. Where we should look for absolute destitution—where we can reckon up nothing but wants—some contrivance always comes in to supply the privation. A *snail*, without wings, feet, or thread, climbs up the stalks of plants by the sole aid of a viscid humour discharged from her skin. She adheres to the stems, leaves, and fruits of plants by means of a sticking-plaster. A *mussel*, which might seem by its helplessness to lie at the mercy of every wave that went over it, has the singular power of spinning strong tendinous threads by which she moors her shell to rocks and timbers. A *cockle*, on the contrary, by means of its stiff tongue, works for itself a shelter in the sand. The provisions of nature extend to cases the most desperate. A *lobster* has in its constitution a difficulty so great that one could hardly conjecture beforehand how nature would dispose of it. In most animals the skin grows with their growth. If, instead of a soft skin, there be a shell, still it admits of a gradual enlargement. If the shell, as in the tortoise, consist of several pieces, the accession of substance is made at the sutures. Bivalve shells grow bigger by receiving an accretion at their edge; it is the same with spiral shells at their mouth. The simplicity of their form admits of this. But the lobster's shell being applied to the limbs of the body, as well as to the body itself, allows not of either of the modes of growth which are observed to take place in other shells. Its hardness resists expansion; and its complexity renders it incapable of increasing its size by addition of substance to its edge. How then was the growth of the lobster to be provided for? Was room to be made for it in the old shell, or was it to be successively fitted with new ones? If a change of shell became necessary, how was the lobster to extricate himself from his present confinement? how was he to uncase his buckler, or draw his legs out of his boots? The process which fishermen have observed to take place is as follows. At certain seasons the shell of the lobster grows soft; the animal swells its body; the seams open, and the claws burst at the joints. When the shell has thus become loose upon the body, the animal makes a second effort, and by a tremulous spasmodic motion casts it off. In this state the liberated but defenceless fish retires into holes in the rock. The released body now suddenly pushes its growth. In about eight-and-forty hours a fresh concretion of humour upon the surface, *i. e.* a new shell, is formed, adapted in every part to the increased dimensions of the animal. This wonderful mutation is repeated every year.[65]

If there be imputed defects without compensation, I should suspect that they were defects only in appearance. Thus, the body of the *sloth* has often been reproached for the slowness of its motions, which has been attributed to an imperfection in the formation of its limbs. But it ought to be observed that it is this slowness which alone suspends the voracity of the animal. He fasts during his migration from one tree to another: and this fast may be necessary for the relief of his overcharged vessels, as well as to allow time for the concoction of the mass of coarse and hard food which he has taken into his stomach. The tardiness of his pace seems to have reference to the capacity of his organs, and to his propensities with respect to food—*i. e.*, is calculated to counteract the effects of repletion.

[65] See Appendix.

Or there may be cases in which a defect is artificial, and compensated by the very cause which produces it. Thus the *sheep*, in the domesticated state in which we see it, is destitute of the ordinary means of defence or escape—is incapable either of resistance or flight. But this is not so with the wild animal. The natural sheep is swift and active; and, if it lose these qualities when it comes under the subjection of man, the loss is compensated by his protection. Perhaps there is no species of quadruped whatever which suffers so little as this does from the depredation of animals of prey.

For the sake of making our meaning better understood, we have considered this business of compensation under certain *particularities* of constitution in which it appears to be most conspicuous. This view of the subject necessarily limits the instances to single species of animals. But there are compensations, perhaps not less certain, which extend over large classes and to large portions of living nature.

I. In quadrupeds, the deficiency of teeth is usually *compensated* by the faculty of rumination. The sheep, deer, and ox tribe are without fore teeth in the upper jaw.[66] These ruminate. The horse and ass are furnished with teeth in the upper jaw, and do not ruminate. In the former class, the grass and hay descend into the stomach nearly in the state in which they are cropped from the pasture or gathered from the bundle. In the stomach they are softened by the gastric juice, which in these animals is unusually copious: thus softened and rendered tender, they are returned a second time to the action of the mouth, where the grinding teeth complete at their leisure the trituration which is necessary, but which was before left imperfect: I say the trituration which is necessary; for it appears from experiments that the gastric fluid of sheep, for example, has no effect in digesting plants unless they have been previously masticated; that it only produces a slight maceration, nearly as common water would do in a like degree of heat; but

[66] See the account of the teeth, in the Appendix.

that when once vegetables are reduced to pieces by mastication, the fluid then exerts upon them its specific operation. Its first effect is to soften them, and to destroy their natural consistency: it then goes on to dissolve them, not sparing even the toughest parts, such as the nerves of the leaves.*

I think it very probable that the gratification also of the animal is renewed and prolonged by this faculty. Sheep, deer, and oxen appear to be in a state of enjoyment whilst they are chewing the cud: it is then, perhaps, that they best relish their food.[67]

* Spall. Dis. iii. sect. cxl.

[67] Wherever a seed can lodge we find vegetables growing, and wherever we find digestible matter there are animals to live upon it; and the kind of food determines the organization of the creature, not resulting from it, but provided for it. The class of ruminants feed on the coarser herbage where the vegetable is in abundance, but the actual nutritious matter is small in quantity compared with the mass. There is therefore an obvious necessity for a more complex apparatus to extract the smaller proportion of matter capable of being animalized: hence the maceration in the first stomach, hence the regurgitation and rumination, and the reception into the second and third stomach, in preparation for the proper digestion in the last. When the mass is digested, the nutritious part is still small in proportion to the whole; and to permit that smaller portion of aliment to be absorbed and carried into the system, the intestinal canal must be long and complex, offering resistance to the rapid descent of the food, and giving it lodgment: and thus there is always a correspondence between the complication of the stomach and the length of the intestines, and between both and the nature of the food. It is further very remarkable, that when animals of the same species live in different climates, where there is more or less abundance of vegetable food, there is an adaptation of their digestive organs. Where it is abundant, the configuration of the intestines which is intended to delay its descent is less complex. Where the food is more scarce, the intestine is longer, and the valvular obstruction greater. This has been observed by Sir E. Home, in comparing the cassowary of Java with the cassowary of New South Wales, and the American ostrich with the same bird

II. In birds, the *compensation* is still more striking. They have no teeth at all. What have they then to make up for this severe want? I speak of granivorous and herbivorous birds; such as common fowls, turkeys, ducks, geese, pigeons, &c.; for it is concerning these alone that the question need be asked. All these are furnished with a peculiar and most powerful muscle, called the *gizzard;* the inner coat of which is fitted up with rough plaits, which, by a strong friction against one another, break and grind the hard aliment as effectually, and by the same mechanical action, as a coffee-mill would do. It has been proved by the most correct experiments, that the gastric juice of these birds will not operate upon the *entire* grain: not even when softened by water or macerated in the crop. Therefore, without a grinding machine within its body, without the trituration of the gizzard, a chicken would have starved upon a heap of corn. Yet, why should a bill and a gizzard go together? why should a gizzard never be found where there are teeth?

Nor does the gizzard belong to birds as such. A gizzard is not found in birds of prey: *their* food requires not to be ground down in a mill. The compensatory contrivance goes no farther than the necessity. In both classes of birds, however, the digestive organ within the body bears a strict and mechanical relation to the external instruments for procuring food. The soft membranous stomach accompanies a hooked notched beak; short muscular legs; strong, sharp, crooked talons:—the cartilaginous stomach attends that conformation of bill and toes which restrains the bird to the picking of seeds or the cropping of plants.[68]

inhabiting the deserts of Africa. The same comparison has been made between the Leicestershire sheep and the mountain sheep of Scotland.

[68] We have said that it is the object to support animal life, and to give the enjoyment of existence; and that wherever the means are afforded of converting a material under the processes of digestion and assimilation, there animals will be found with an apparatus of digestion adapted to the food.

III. But to proceed with our *compensations*. A very numerous and comprehensive tribe of terrestrial animals are entirely without feet—yet locomotive, and in a very considerable degree swift in their motion. How is the *want of feet* compensated? It is done by the disposition of the muscles and fibres of the trunk. In consequence of the just collocation and by means of the joint action of longitudinal and annular fibres—that is to say, of strings and rings—the body and train of reptiles are capable of being reciprocally shortened and lengthened, drawn up and stretched out. The result of this action is a progressive and in some cases a rapid movement of the whole body, in any direction to which the will of the animal determines it. The meanest creature is a collection of wonders. The play of the rings in an

Nothing certainly can be more curious than the vicarious action of the stomach and mouth. We see, for example, that where the bill precludes mastication in the mouth, it is performed in the stomach; and then muscles are found in the stomach as powerful as those of the jaws and teeth; and as to the teeth, or what is equivalent to them, we may say that they are continually renewed. In fact, no mechanical structure of jaws and teeth could answer the purposes of nature here: no union of bone and enamel in the tooth could have withstood the attrition of the gizzard; and one of the most beautiful and interesting appliances of nature is the substitution, through the instinct of the animal, of small stones of hard texture, generally consisting of silex, introduced within the grasp and action of this organ. It is a further proof that the mastication, if we may use the term, is more perfect in the gizzard than where there is the most complex structure of teeth, and therefore that it is the means of extracting the greater quantity of nutritious matter. Accordingly, there are gizzards in most classes of animals. They are not only found in birds, but in reptiles. The sea-turtle has what is termed a muscular stomach. Among fishes, the mullet and the gillaroo trout have muscular stomachs. The cuttle-fish, the nautilus, and even the earth-worm, have a crop and gizzard; and insects, according as they live on a leaf or suck the blood, have the same difference in the internal arrangement of the structure for assimilation as that which distinguishes the ox from the lion.

earth-worm, as it crawls, the undulatory motion propagated along the body, the beards or prickles with which the annuli are armed, and which the animal can either shut up close to its body, or let out to lay hold of the roughness of the surface upon which it creeps, and the power arising from all these of changing its place and position, afford, when compared with the provisions for motion in other animals, proofs of new and appropriate mechanism. Suppose that we had never seen an animal move upon the ground without feet, and that the problem was: Muscular action, *i. e.* reciprocal contraction and relaxation, being given, to describe how such an animal might be constructed capable of voluntarily changing place. Something, perhaps, like the organization of reptiles might have been hit upon by the ingenuity of an artist; or might have been exhibited in an automaton, by the combination of springs, spiral wires, and ringlets; but to the solution of the problem would not be denied, surely, the praise of invention and of successful thought: least of all could it ever be questioned whether intelligence had been employed about it or not.[69]

[69] Not unconnected with the subject of the last note is the progression of animals: and we have none better suited for the object of this volume than the consideration of the infinite variety of the instruments of motion, from the blubber that floats like froth upon the water, to the eagle or the antelope. The genus *medusa* of Linnæus embraces those animals like jelly which float in the sea. Some of these, when taken out of the water, will weigh fifty ounces, and, on being dried, not more than five or six grains. From this it would appear that they must be of the specific gravity of water, and hence their peculiar organization and mode of existence; especially it accounts for their mode of progression, if it can be called so: since they are in a great measure passive, and float and are carried by the wind. For this purpose there is a vesicle or bladder filled with air, which in some rises above the water, and the animal is dragged as we might imagine a balloon would be after lighting on the water. The walls of this sac are muscular, and the animal, by retaining or forcing out the air, can either take advantage of the wind, and is sometimes moved with great velocity, or

sink under the surface, and move only with the current. There is every reason to believe that the air, which is the principal means of change of place, is secreted by the animal.

From some of these animals tentacula hang down into the water for seizing their food, and perhaps for directing their progress. They have a power of distending them, or erecting them by forcing water into their texture, by the contraction of vesicles near their base. Varieties of these animals hoist a plate or crest out of the water, which has a still greater resemblance to a sail.

We have already noticed the fins of fishes, the wing of the bird, and the web-foot of the duck. "The meanest creature is, indeed, a collection of wonders." In the earth-worm or the caterpillar, the head, or the anterior part of the body, is projected (and it is a difficult problem to produce extension by contraction) till it touches the ground, and slightly adheres to it, when the posterior part of the body is drawn forwards. In many worms or caterpillars there are holders discoverable upon minute inspection, and their anatomy exhibits a perfect set of muscles attached to those exterior rough points,—by which it is made evident that each of them is a foot. But nothing is more interesting than to see the change of the larva to the winged insect, where these muscles and their appropriate nerves disappear: and new muscles, and new nerves, and new energies direct the creature that crept an inch in an hour to outstrip, as we have said, the fleetest horse, or to rise upon the wind; for those who travel by the rail-roads observe bees to fly round them, and therefore to move above sixty miles an hour. The contrasts are the most curious between the flight of the bat and the motion of the mole; the same organization being calculated, with slight adaptation, for the atmosphere, and for moving under the earth. We might almost give the instance of the perforation of solid calcareous rock by the boring mollusca, which, by late observations, seems to be accomplished by means of the foot.

END OF VOLUME II.

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