PALEY'S
NATURAL THEOLOGY,

WITH

ILLUSTRATIVE NOTES,

BY

HENRY LORD BROUGHAM, F.R.S.
AND MEMBER OF THE NATIONAL INSTITUTE OF FRANCE,

AND

SIR CHARLES BELL, K.G.H., F.R.S., L. & E.
PROFESSOR OF SURGERY IN THE UNIVERSITY OF EDINBURGH, FORMERLY OF THE COUNCIL, AND PROF. ANAT. ROY. COLL. SURG. LONDON, ETC. ETC.

TO WHICH ARE ADDED

SUPPLEMENTARY DISSERTATIONS,

BY SIR CHARLES BELL.

WITH NUMEROUS WOOD-CUTS.

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NATURAL THEOLOGY.

CHAPTER XXI.

THE ELEMENTS.

When we come to the elements, we take leave of our mechanics; because we come to those things, of the organisation of which, if they be organised, we are confessedly ignorant. This ignorance is implied by their name. To say the truth, our investigations are stopped long before we arrive at this point. But then it is for our comfort to find, that a knowledge of the constitution of the elements is not necessary for us. For instance, as Addison has well observed, "we know *water* sufficiently, when we know how to boil, how to freeze, how to evaporate, how to make it fresh, how to make it run or spout out, in what quantity and direction we please, without knowing what water is." The observation of this excellent writer has more propriety in it now, than it had at the time it was made; for the constitution and the constituent parts of water appear in some measure to have been lately discovered; yet it does not, I think, appear, that we can make any better or greater use of water since the discovery than we did before it.

We can never think of the elements, without reflecting upon the number of distinct uses which are *consolidated* in the same substance. The *air* supplies the lungs, supports fire, conveys sound, reflects light, diffuses smells, gives rain, wafts ships, bears up birds. 'Εξ ὑδατος τα παντα: *water*, besides maintaining its own inhabitants, is the universal nourisher of plants, and through them of terrestrial animals; is the basis of their juices and fluids; dilutes their food; quenches their thirst; floats their burdens. *Fire* warms, dissolves, enlightens: is the great promoter of vegetation and life, if not necessary to the support of both.

We might enlarge, to almost any length we please, upon each of these uses; but it appears to me almost sufficient to state them. The few remarks, which I judge it necessary to add, are as follow:—

I. Air is essentially different from earth. There appears to be no necessity for an atmosphere's investing our globe; yet it does invest it: and we see how many, how various, and how important are the purposes which it answers to every order of animated, not to say of organised, beings, which are placed upon the terrestrial surface. I think that every one of these uses will be understood upon the first mention of them, except it be that of *reflecting* light, which may be explained thus:—If I had the power of seeing only by means of rays coming directly from the sun, whenever I turned my back upon the luminary, I should find myself in darkness. If I had the power of seeing by reflected light, yet by means only of light reflected from solid masses, these masses would shine indeed, and glisten, but it would be in the dark. The hemisphere, the sky, the world, could only be *illuminated*, as it is illuminated, by the light of the sun being from all sides, and in every direction, reflected to the eye, by particles, as numerous, as thickly scattered, and as widely diffused, as are those of the air.

Another general quality of the atmosphere is the power of evaporating fluids. The adjustment of this quality to our use is seen in its action upon the sea. In the sea, water and salt are mixed together most intimately; yet the atmosphere raises the water, and leaves the salt. Pure and fresh as drops of rain descend, they are collected from brine. If evaporation be solution (which seems to be probable) then the air dissolves the water, and not the salt. Upon whatever it be founded, the distinction is critical: so much so, that when we attempt to imitate the process by art, we must regulate our distillation with great care and nicety, or, together with the water, we get the bitterness, or at least the distastefulness, of the marine substance;—and, after all, it is owing to this original elective power in the air, that we can effect the separation which we wish, by any art or means whatever.

By evaporation, water is carried up into the air; by the converse of evaporation, it falls down upon the earth. And how does it fall? Not by the clouds being all at once re-converted into water, and descending like a sheet; not in rushing down in columns from a spout; but in moderate drops, as from a colander. Our watering-pots are made to imitate showers of rain. Yet, *à priori*, I should have thought either of the two former methods more likely to have taken place than the last.

By respiration, flame, putrefaction, air is rendered unfit for the support of animal life. By the constant operation of these corrupting principles, the whole atmosphere, if there were no restoring causes, would come at length to be deprived of its necessary degree of purity. Some of these causes seem to have been discovered, and their efficacy ascertained by experiment; and so far as the discovery has proceeded, it opens to us a beautiful and a wonderful economy. *Vegetation* proves to be one of them. A sprig of mint, corked up with a small portion of foul air, placed in the light, renders it again capable of supporting light or flame. Here, therefore, is a constant circulation of benefits maintained between the two great provinces of organised nature. The plant purifies what the animal has poisoned; in return, the contaminated air is more than ordinarily nutritious to the plant.[1] *Agitation with*

[1] The experiments of Priestley, confirmed by those of Ingenhouz and Saussure, led to the conclusion that the air is kept pure by the action of plants, these emitting more oxygen gas by day than carbonic acid gas by night. Some doubt was thrown upon this point by the experiments of Mr. Ellis; but these appear to have been removed by Sir H. Davy's remarks and experiments. It seems probable that the plant, growing in the light, decomposes both the carbonic acid which exists, though in a very small proportion, in the atmosphere, and also any that may exist in the water applied to its leaves; for Sennebier found that when these are immersed in water impregnated with carbonic acid, oxygen gas was evolved, but not if water was used which had been boiled.

The process of vegetation appears to be the great means of supplying the loss of oxygen in the atmosphere; indeed, none other have been as yet discovered.

water turns out to be another of these restoratives. The foulest air, shaken in a bottle with

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The composition of the atmosphere, in respect of purity, though at one time supposed to vary in different places, is now ascertained to be everywhere invariably the same. It contains about 20 parts of oxygen gas, by measure, in 100, and the remaining 80 are almost entirely nitrogen gas. The only variation is in the slight portion of carbonic acid gas, which never exceeds 1 in 100, and is seldom more than 1 in 1000, supposing the circulation of the air to be unconfined. But the proportion of oxygen to the whole bulk has been found to be the same at nearly 22,000 feet high, and in the deepest valleys; the same in countries widely remote from each other, and differing in climate as well as soil; the same in the most pestilential marshes, or in hospitals, and in the most open and healthy situations. The agitation of the air by winds speedily mixes all its strata, and prevents the effects of breathing and burning from being perceived. Yet a constant consumption of oxygen is going on, wherever there are either living creatures of the hot-blooded class, or fires of any kind, natural or artificial; and this is so balanced by the process of vegetation, that the uniformity of the air's composition is maintained universally.

The union in which the oxygenous and nitrogenous portions of the atmosphere exist, also merits attention. It is ascertained to be of a peculiar kind; for it is not merely that of mechanical admixture—the union of water for a sufficient length of time, recovers a great degree of its purity.[2] Here then again, allowing for the scale upon which nature works, we see the salutary effects of *storms* and *tempests*. The yesty waves which confound the heaven and

aggregation,—inasmuch as the nitrogen gas, being about a seventh part lighter than the oxygen, would rise to the top, and so make the air of higher elevations more pure, contrary to the fact. Nor is it like most other chemical unions, inasmuch as it is both extremely feeble, and is formed without any diminution in the bulk of the two substances combined together. But the kind of union in which the two gases are held is productive of the most beneficial effects. Their disengagement from each other is so easily accomplished, that there is the greatest facility in supporting flame and respiration; while their mixture is so perfect, that the mischiefs are prevented which would arise from their being exhibited either to the lungs or to heated bodies in their pure state.

[2] That agitation with water will remove certain impurities in the air is undeniable, but not all impurities. Animals by breathing consume the oxygen, leaving carbonic acid gas and nitrogen gas. Water absorbs the former easily, and bulk for bulk; but of the latter it will only absorb 1½ per cent. So of the products of putrefaction, (beside carbonic acid,) carburetted hydrogen, and sulphuretted hydrogen gases, water will absorb of the latter bulk for bulk; but not above 1⅜ per cent. of the former.

the sea, are doing the very thing which was done in the bottle. Nothing can be of greater importance to the living creation, than the salubrity of their atmosphere. It ought to reconcile us, therefore, to these agitations of the elements, of which we sometimes deplore the consequences, to know that they tend powerfully to restore to the air that purity which so many causes are constantly impairing.

II. In Water, what ought not a little to be admired, are those negative qualities which constitute its *purity*. Had it been vinous, or oleaginous, or acid; had the sea been filled, or the rivers flowed, with wine or milk, fish, constituted as they are, must have died; plants, constituted as they are, would have withered; the lives of animals which feed upon plants must have perished. Its very *insipidity*, which is one of those negative qualities, renders it the best of all menstrua. Having no taste of its own, it becomes the sincere vehicle of every other. Had there been a taste in water, be it what it might, it would have infected every thing we ate or drank, with an importunate repetition of the same flavour.

Another thing in this element, not less to be admired, is the constant *round* which it travels; and by which, without suffering either adulteration or waste, it is continually offering itself to the wants of the habitable globe. From the sea are exhaled those vapours which form the clouds: these clouds descend in showers, which, penetrating into the crevices of the hills, supply springs; which springs flow in little streams into the valleys; and there uniting, become rivers; which rivers, in return, feed the ocean. So there is an incessant circulation of the same fluid; and not one drop probably more or less now than there was at the creation. A particle of water takes its departure from the surface of the sea, in order to fulfil certain important offices to the earth; and having executed the service which was assigned to it, returns to the bosom which it left.

Some have thought that we have too much water upon the globe, the sea occupying above three-quarters of its whole surface. But the expanse of ocean, immense as it is, may be no more than sufficient to fertilize the earth. Or, independently of this reason, I know not why the sea may not have as good a right to its place as the land. It may proportionably support as many inhabitants; minister to as large an aggregate of enjoyment. The land only affords a habitable surface; the sea is habitable to a great depth. . . .

III. Of Fire, we have said that it *dissolves*. The only idea probably which this term raised in the reader's mind, was that of fire melting metals, resins, and some other substances, fluxing ores, running glass, and assisting us in many of our operations, chemical or culinary. Now these are only uses of an occasional kind, and give us a very imperfect notion of what fire does for us. The grand importance of this dissolving power, the great office indeed of fire in the economy of nature, is keeping things in a state of solution—that is to say, in a state of fluidity. Were it not for the presence of heat, or of a certain degree of it, all fluids would be frozen. The ocean itself would be a quarry of ice ; universal nature stiff and dead.

We see, therefore, that the elements bear not only a strict relation to the constitution of organised bodies, but a relation to each other. Water could not perform its office to the earth without air ; nor exist, as water, without fire. [3]

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[3] The conducting powers of different substances are beautifully adapted to the wants of the animal and vegetable kingdom. Snow is so bad a conductor, that it protects the ground effectually in rigorous climates. It is said that in Siberia there have been known to be as many as 38 degrees (Fahrenheit) of difference between the temperature of the air and that of the ground under the snow ; the latter not being cooled much below the

IV. Of Light (whether we regard it as of the same substance with fire, or as a different substance), it is altogether superfluous to expatiate upon the use. No man disputes it. The observations, therefore, which I shall offer, respect that little which we seem to know of its constitution.

Light travels from the sun at the rate of twelve millions of miles in a minute. Urged by such a velocity, with what *force* must its particles drive against (I will not say the eye, the tenderest of animal substances, but) every substance, animate or inanimate, which stands in its way! It might seem to be a force sufficient to shatter to atoms the hardest bodies.

How then is this effect, the consequence of such prodigious velocity, guarded against? By

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freezing point. So, too, the animal which, transported to warmer climates, becomes covered with hair, has in its own cold country a woolly covering, and this conducts heat so slowly as to accumulate that which respiration is continually producing.

The peculiarity which distinguishes water from other fluids in freezing, likewise merits attention. It expands, instead of continuing to contract, when cooled to the freezing point; and this has the useful effect of crumbling earth and even rocks, so as to render them fit for assisting the process of vegetation.

a proportionable *minuteness* of the particles of which light is composed. It is impossible for the human mind to imagine to itself any thing so small as a particle of light. But this extreme exility, though difficult to conceive, it is easy to prove. A drop of tallow, expended in the wick of a farthing candle, shall send forth rays sufficient to fill a hemisphere of a mile diameter; and to fill it so full of these rays, that an aperture not larger than the pupil of an eye, wherever it be placed within the hemisphere, shall be sure to receive some of them. What floods of light are continually poured from the sun, we cannot estimate; but the immensity of the sphere which is filled with particles, even if it reached no farther than the orbit of the earth, we can in some sort compute; and we have reason to believe, that, throughout this whole region, the particles of light lie, in latitude at least, near to one another. The spissitude of the sun's rays at the earth is such, that the number which falls upon a burning-glass of an inch diameter, is sufficient, when concentrated, to set wood on fire.

The tenuity and the velocity of particles of light, as ascertained by separate observations may be said to be proportioned to each other, both surpassing our utmost stretch of comprehension; but proportioned. And it is this proportion alone which converts a tremendous element into a welcome visiter.

It has been observed to me by a learned friend, as having often struck his mind, that, if light had been made by a common artist, it would have been of one uniform *colour*: whereas, by its present composition, we have that variety of colours which is of such infinite use to us for the distinguishing of objects; which adds so much to the beauty of the earth, and augments the stock of our innocent pleasures.

With which may be joined another reflection, viz.—that, considering light as compounded of rays of seven different colours (of which there can be no doubt, because it can be resolved into these rays by simply passing it through a prism), the constituent parts must be well mixed and blended together, to produce a fluid so clear and colourless, as a beam of light is, when received from the sun. [4]

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[4] The substitution of the undulatory for the atomic theory of light would produce no alteration whatever in the author's conclusions; and, so far from diminishing, would rather increase the astonishment which the phenomena of Optics are calculated to excite. The same may be said of the discoveries made partly since Dr. Paley's time, partly immediately before the composition

of his work, of the two other kinds of rays which accompany those of light; the *calorific*, or heat-making, which partly mix with the *colorific*, or colour-making, of the spectrum, and partly fall beyond the least refrangible rays; and the *chemical*, which affect certain metallic salts, without either producing illumination or exciting heat, and which are to be found among and beyond the most refrangible rays: So that a beam of white light consists of three kinds of ray, and one of these kinds consists of seven subdivisions, at least according to the Newtonian theory, which divides the colours into seven instead of innumerable gradations of shades.

CHAPTER XXII.

ASTRONOMY.*

My opinion of Astronomy has always been that it is *not* the best medium through which to prove the agency of an intelligent Creator; but that, this being proved, it shows, beyond all other sciences, the magnificence of his operations. The mind which is once convinced, it raises to sublimer views of the Deity than any other subject affords; but it is not so well adapted as some other subjects are to the purpose of argument. We are destitute of the means of examining the constitution of the heavenly bodies. The very simplicity of their appearance is against them. We see nothing but bright points, luminous circles, or the phases of spheres reflecting the light which falls upon them. Now we deduce design from relation, aptitude, and correspondence of *parts*. Some degree, therefore, of *complexity*

* For the articles of this chapter marked with an asterisk, I am indebted to some obliging communications received (through the hands of the Lord Bishop of Elphin) from the Rev. J. Brinkley, M.A., Andrew's Professor of Astronomy in the University of Dublin. —(*Note of the Author.*)—[Professor Brinkley was afterwards, as is well known, Bishop of Cloyne. His lordship, upon being made acquainted with the plan of the present publication, kindly communicated the notes now added, and which are marked with his name.]

is necessary to render a subject fit for this species of argument. But the heavenly bodies do not, except perhaps in the instance of Saturn's ring, present themselves to our observation as compounded of parts at all. This, which may be a perfection in them, is a disadvantage to us, as inquirers after their nature. They do not come within our mechanics.

And what we say of their forms is true of their *motions*. Their motions are carried on without any sensible intermediate apparatus; whereby we are cut off from one principal ground of argumentation—analogy. We have nothing wherewith to compare them; no invention, no discovery, no operation or resource of art, which, in this respect, resembles them. Even those things which are made to imitate and represent them—such as orreries, planetaria, celestial globes, &c., bear no affinity to them, in the cause and principle by which their motions are actuated. I can assign for this difference a reason of utility—*viz.*, a reason why, though the action of *terrestrial* bodies upon each other be, in almost all cases, through the intervention of solid or fluid substances, yet central attraction does not operate in this manner. It was necessary that the intervals between the planetary orbs should be devoid of any *inert* matter, either fluid or solid, because such an intervening substance would, by its resistance, destroy those very motions, which attraction is employed to preserve. This may be a final cause of the difference; but still the difference destroys the analogy.

Our ignorance, moreover, of the *sensitive* natures, by which other planets are inhabited, necessarily keeps from us the knowledge of numberless utilities, relations, and subserviencies, which we perceive upon our own globe.

After all; the real subject of admiration is, that we understand so much of astronomy as we do. That an animal confined to the surface of one of the planets; bearing a less proportion to it than the smallest microscopic insect does to the plant it lives upon; that this little, busy, inquisitive creature, by the use of senses which were given to it for its domestic necessities, and by means of the assistance of those senses which it has had the art to procure, should have been enabled to observe the whole system of worlds to which its own belongs; the changes of place of the immense globes which compose it; and with such accuracy as to mark out beforehand the situation in the heavens in which they will be found at any future point of time; and that these bodies, after sailing through regions of void and trackless space, should arrive at the place where they were expected, not within a minute, but within a few seconds of a minute, of the time prefixed and predicted: all this is wonderful, whether we refer our admiration to the constancy of the heavenly motions themselves, or to the perspicacity and precision with which they have been noticed by mankind. Nor is this the whole, nor indeed the chief part, of what astronomy teaches. By bringing reason to bear upon observation (the acutest reasoning upon the exactest observation), the astronomer has been able, out of the "mystic dance," and the confusion (for such it is) under which the motions of the heavenly bodies present themselves to the eye of a mere gazer upon the skies, to elicit their order and their real paths.

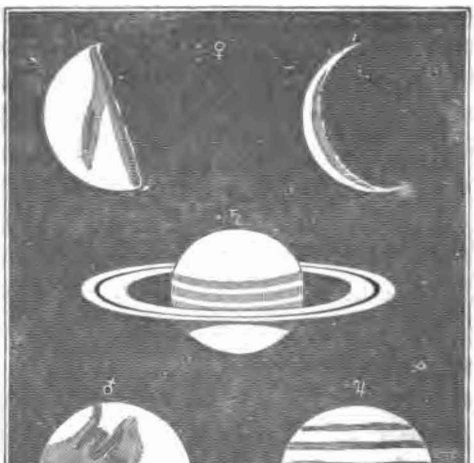
Our knowledge, therefore, of astronomy is admirable, though imperfect; and, amidst the confessed desiderata and desideranda, which impede our investigation of the wisdom of the Deity in these the grandest of his works, there are to be found, in the phenomena, ascertained circumstances and laws, sufficient to indicate an intellectual agency in three of its principal operations, viz. in choosing, in determining, in regulating; in *choosing*, out of a boundless variety of suppositions which were equally possible, that which is beneficial; in *determining*, what, left to itself, had a thousand chances against conveniency, for one in its favour; in *regulating* subjects, as to quantity and degree, which, by their nature, were unlimited with respect to either. It will be our business to offer, under each of these heads, a few instances, such as best admit of a popular explication [5].

[5] This cut represents a telescopic view of the Sun, showing some of the remarkable spots which have occasionally appeared on its surface, the largest sometimes exceeding the size of the whole Earth. Astronomers by closely observing the motion which these spots have across the Sun's disc, and the perspective changes which they undergo in assuming a foreshortened, or oval form, as they approach his edge, previous to their disappearance, have greatly assisted the reasoning, which proves his form to be spherical, and that he has a rotation on his axis.

I. Amongst proofs of choice, one is, fixing the source of light and heat in the *centre* of the system. The sun is ignited and luminous; the planets, which move round him, are cold and dark. There seems to be no antecedent necessity for this order. The sun might have been an opaque mass; some one, or two, or more, or any, or all, the planets, globes of fire. There is nothing in the nature of the heavenly bodies which requires that those which are stationary should be on fire, that those which move should be cold; for, in fact, comets are bodies on fire, or at least capable of the most intense heat, yet revolve round a centre: nor does this order obtain between the primary planets and their secondaries, which are all opaque. When we consider, therefore, that the sun is one; that the planets going round it are, at least, seven; that it is indifferent to their nature which are luminous and which are opaque: and also in what order, with respect to each other, these two kinds of bodies are disposed; we may judge of the improbability of the present arrangement taking place by chance.

If, by way of accounting for the state in which we find the solar system, it be alleged (and this is one amongst the guesses of those who reject an intelligent Creator), that the planets themselves are only cooled or cooling masses, and were once, like the sun, many thousand times hotter than red hot iron; then it follows, that the sun also himself must be in his progress towards growing cold; which puts an end to the possibility of his having existed, as he is, from eternity. This consequence arises out of the hypothesis with still more certainty, if we make a part of it, what the philosophers who maintain it have usually taught, that the planets were originally masses of matter, struck off in a state of fusion, from the body of the sun, by the percussion of a comet, or by a shock from some other cause, with which we are not acquainted: for, if these masses, partaking of the nature and substance of the sun's body, have in process of time lost their heat, that body itself, in time likewise, no matter in how much longer time, must lose its heat also, and therefore be incapable of an eternal duration in the state in which we see it, either for the time to come, or the time past.

The preference of the present to any other mode of distributing luminous and opaque bodies, I take to be evident. It requires more astronomy than I am able to lay before the reader to show, in its particulars, what would be the effect to the system, of a dark body at the centre and one of the planets being luminous: but I think it manifest, without either plates or calculation, first, that supposing the necessary proportion of magnitude between the central and the revolving bodies to be preserved, the ignited planet would not be sufficient to illuminate and warm the rest of the system; secondly, that its light and heat would be imparted to the other planets much more irregularly than light and heat are now received from the sun[6].



[6] This cut represents the four great planets, as seen through telescopes of considerable powers. Each planet

(*) II. Another thing, in which a choice appears to be exercised, and in which, amongst the possibilities out of which the choice was to be made, the number of those which were wrong bore an infinite proportion to the number of those which were right, is in what geometricians call the *axis of rotation*. This matter I will endeavour to explain. The earth, it is well known,

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is marked by the symbol which astronomers have for ages been accustomed to use. ♄ is Saturn with his two rings; which are huge bodies, the larger having a diameter more than 25 times that of our earth, or above 200,000 miles, and moving with prodigious swiftness round the planet. The seven satellites, or moons, are not represented. ♃ is Jupiter with his spots or belts; his four moons are not represented. Both Saturn and Jupiter are, like our earth, flattened at the poles, instead of being perfect spheres, owing to their rotatory motion on their axes. ♂ is Mars, with his singularly-formed spots, and reddish light at his poles. ♀ is two figures of Venus, as she is seen in different positions; one like a half-moon, and in the other like a crescent. These *appearances* are called *phases*, from the Greek, and she is the brightest of all the planets. The bulk of Jupiter is 1281 times greater than that of the Earth, of Saturn 995 times; while that of Venus is nine-tenths and that of Mars one-half the Earth's bulk. The bulk of the Sun itself is 1,367,000 times that of the earth.

is not an exact globe, but an oblate spheroid, something like an orange. Now the axes of rotation, or the diameters upon which such a body may be made to turn round, are as many as can be drawn through its centre to opposite points upon its whole surface; but of these axes none are *permanent*, except either its shortest diameter, *i. e.* that which passes through the heart of the orange from the place where the stalk is inserted into it, and which is but one; or its longest diameters, at right angles with the former, which must all terminate in the single circumference which goes round the thickest part of the orange. The shortest diameter is that upon which in fact the earth turns, and it is, as the reader sees, what it ought to be, a permanent axis; whereas, had blind chance, had a casual impulse, had a stroke or push at random, set the earth a-spinning, the odds were infinite but that they had sent it round upon a wrong axis. And what would have been the consequence? The difference between a permanent axis and another axis is this: When a spheroid in a state of rotatory motion gets upon a permanent axis, it keeps there; it remains steady and faithful to its position: its poles preserve their direction with respect to the plane and to the centre of its orbit: but, whilst it turns upon an axis which is *not* permanent (and the number of those we have seen infinitely exceeds the number of the other), it is always liable to shift and vacillate from one axis to another, with a corresponding change in the inclination of its poles. Therefore, if a planet once set off revolving upon any other than its shortest, or one of its longest axes, the poles on its surface would keep perpetually changing, and it never would attain a permanent axis of rotation. The effect of this unfixedness and instability would be, that the equatorial parts of the earth might become the polar, or the polar the equatorial; to the utter destruction of plants and animals, which are not capable of interchanging their situations, but are respectively adapted to their own. As to ourselves, instead of rejoicing in our temperate zone, and annually preparing for the moderate vicissitude, or rather the agreeable succession, of seasons, which we experience and expect, we might come to be locked up in the ice and darkness of the arctic circle, with bodies neither inured to its rigours, nor provided with shelter or defence against them. Nor would it be much better, if the trepidation of our pole, taking an opposite course, should place us under the heats of a vertical sun. But if it would fare so ill with the human inhabitant, who can live under greater varieties of latitude than any other animal; still more noxious would this translation of climate have proved to life in the rest of the creation; and, most perhaps of all, in plants. The habitable earth, and its beautiful variety, might have been destroyed by a simple mischance in the axis of rotation[7].

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[7] (Note of Bishop Brinkley.) Either the earth was created a solid, an oblate spheroid, as it now exists, or it must have taken its present form while a soft or fluid mass. In the former case, the argument for design arising from the body revolving on a permanent axis of rotation is of the strongest possible nature. But the present extended knowledge of geology has rendered it highly probable that the earth was originally an ignited mass in a state of fluidity, ignited to the very surface, and by its rotation in that state took its present form as the result of the mutual attraction of its parts and of its rotatory motion. This must be conceded if we do not admit the choice of a permanent axis of rotation. It is, therefore, in the progress through countless ages of the changes on the surface, from the chaotic or primary formation of the geologists to the most interesting state of the surface as it now exists, that we trace the endless arguments for design. However difficult at first sight to be explained, these changes will, when understood, show *one uniform* system, in which all things work together for good.

If we consider the state of the surface before its cooling

(*) III. All this, however, proceeds upon a supposition of the earth having been formed at

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in a great degree, it must have been wholly unfitted for animal and vegetable life. The admission of this state necessarily lets in the *posterior* and *successive* creation of vegetables and animals. From the vestiges which remain we may conclude, with the highest degree of probability, that for a very long period the surface was only adapted for vegetables and the lowest description of animal life; afterwards for animals of an amphibious nature, and such as could exist only on the marshy shores of lakes, or in places occasionally covered with water. By degrees this state of the surface gave way to others more fitted for a further supply of animals *to be created.* The principal origin of these changes appears to have been provided in the powers attached to the substances, of whatever nature they may be, existing in the interior of the earth; but these powers have been merely mechanical, and could not originate organized vegetables and animals. The class of changes at the surface, constituting the tertiary formations of the geologist, appear to have been that which was followed by the introduction of a great variety of large animals, many of which are now extinct. The surface was still to be further improved by making it fitted for a wide extension of animals and of their food. This has been done by the means afforded for the extension and spreading of alluvial matter, so admirably adapted for the growth of plants, and therefore for the existence of animal life.

first an oblate spheroid. There is another supposition; and perhaps our limited information will not enable us to decide between them. The second supposition is, that the earth, being a mixed mass somewhat fluid, took, as it might do, its present form, by the joint action of the mutual gravitation of its parts and its rotatory motion. This, as we have said, is a point in the history of the earth, which our observations are not suffi-

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The changes of surface which have been alluded to are all parts of the same design. Between the successive changes great intervals appear to have elapsed. The imagination is able to form no conception of the length of time since the chaotic state began to change. Notwithstanding the time that must have existed between each change, one uniform plan can be discerned. The animals which we must admit to have been *successively* created, show, by their organization, the same creator. Thus, if we admit the fluid and chaotic state of the earth (the alternative if we do not admit an original spheroidal formation) there cannot be a question as to the powerful arguments to be derived from the change on the surface and its series of organized beings. Indeed, if the matter be well considered, it will appear to many that the most conclusive arguments for design and *continued* superintendence may be deduced from the researches of the modern geologists.—See Second Note to Chap. xxv. *infra*.

cient to determine. For a very small depth below the surface (but extremely small—less, perhaps, than an eight thousandth part, compared with the depth of the centre), we find vestiges of ancient fluidity. But this fluidity must have gone down many hundred times farther than we can penetrate, to enable the earth to take its present oblate form; and whether any traces of this kind exist to that depth we are ignorant. Calculations were made a few years ago of the mean density of the earth, by comparing the force of its attraction with the force of attraction of a rock of granite, the bulk of which could be ascertained: and the upshot of the calculation was, that the earth upon an average, through its whole sphere, has twice the density of granite, or above five times that of water. Therefore it cannot be a hollow shell, as some have formerly supposed; nor can its internal parts be occupied by central fire or by water. The solid parts must greatly exceed the fluid parts: and the probability is, that it is a solid mass throughout, composed of substances more ponderous the deeper we go. Nevertheless, we may conceive the present face of the earth to have originated from the revolution of a sphere covered by a surface of a compound mixture; the fluid and solid parts separating, as the surface becomes quiescent. Here then comes in the *moderating* hand of the Creator. If the water had exceeded its present proportion, even but by a trifling quantity, compared with the whole globe, all the land would have been covered: had there been much less than there is there would not have been enough to fertilize the continent. Had the exsiccation been progressive, such as we may suppose to have been produced by an evaporating heat, how came it to stop at the point at which we see it? Why did it not stop sooner? why at all? The mandate of the Deity will account for this; nothing else will.

IV. OF CENTRIPETAL FORCES. By virtue of the simplest law that can be imagined, viz. that a body *continues* in the state in which it is, whether of motion or rest; and, if in motion, goes on in the line in which it was proceeding, and with the same velocity, *unless* there be some cause for change: by virtue, I say, of this law, it comes to pass (what may appear to be a strange consequence), that cases arise, in which attraction, incessantly drawing a body towards a centre, never brings, nor ever will bring, the body to that centre, but keep it in eternal circulation round it. If it were possible to fire off a cannon-ball with a velocity of five miles in a second, and the resistance of the air could be taken away, the cannon-ball would for ever wheel round the earth instead of falling down upon it. This is the principle which sustains the heavenly motions. The Deity having appointed this law to matter (than which, as we have said before, no law could be more simple) has turned it to a wonderful account in constructing planetary systems.

The actuating cause in these systems is an attraction which varies reciprocally as the square of the distance; that is, at double the distance, has a quarter of the force; at half the distance, four times the strength; and so on. Now concerning this law of variation, we have three things to observe; first, that attraction, for any thing we know about it, was just as capable of one law of variation as of another; secondly, that, out of an infinite number of possible laws, those which were admissible for the purpose of supporting the heavenly motions lay within certain narrow limits: thirdly, that of the admissible laws, or those which come within the limits prescribed, the law that actually prevails is the most beneficial. So far as these propositions can be made out, we may be said, I think, to prove *choice*, and *regulation*: choice, out of boundless variety; and regulation, of that which, by its own nature, was, in respect of the property regulated, indifferent and indefinite.

I. First, then, attraction, for anything we know about it, was originally indifferent to all laws of variation depending upon change of distance, *i. e.* just as susceptible of one law as of another. It might have been the same at all distances; it might have increased as the distance increased: or it might have diminished with the increase of the distance, yet in ten thousand different proportions from the present; it might have followed no stated law at all. If attraction be what Cotes, with many other Newtonians, thought it to be, a primordial property of matter, not dependent upon, or traceable to, any other material cause; then, by the very nature and definition of a primordial property, it stood indifferent to all laws. If it be the agency of something immaterial; then also, for anything we know of it, it was indifferent to all laws. If the revolution of bodies round a centre depend upon vortices, neither are these limited to one law more than another.[8]

[8] The notion of gravitation being a quality inherent in matter, and which could not be separated from its other qualities, has long been abandoned. To argue that it is *necessarily* inherent never could be consistent with the most ordinary perception of the meaning affixed to the terms necessary and contingent. All that could really be intended, therefore, is what we have just now stated in the first sentence of this note. But that, too, appears wholly groundless. The only appearance of a

There is, I know, an account given of attraction, which should seem, in its very cause, to assign to it the law which we find it to observe; and which, therefore, makes that law, a law, not of choice, but of necessity; and it is the account which ascribes attraction to an *emanation* from

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reason was derived from the intensity of all streams of matter proceeding from a centre in every direction being weakened in proportion to their diffusion, and their diffusion being proportioned to the squares of the distance (by similar triangles and the property of the circle, and generally of similar figures). But suppose we overlook the purely hypothetical nature of the connexion between such emanations and gravitation, (sanctioned as the theory in a certain degree seems to be by no less an authority than *Laplace*, *Méc. Cél.* liv. xv. c. 1,) and admit the hypothesis that matter, according to its present constitution in other respects, must have gravitation in the inverse duplicate ratio; though an important position may be thus gained or granted in Natural Philosophy, nothing whatever is effected in Natural Theology; for the same power which endowed matter with those qualities from whence this peculiar kind of attractive force results, is only proved to have created that attractive force and bestowed it upon matter mediately instead of immediately. This, in short, is only another instance of the argument formerly adverted to under the head of "Instinct," Chap. xviii., and which we there stated to be of general application.

the attracting body. It is probable, that the influence of such an emanation will be proportioned to the spissitude of the rays of which it is composed; which spissitude, supposing the rays to issue in right lines on all sides from a point, will be reciprocally as the square of the distance. The mathematics of this solution we do not call in question: the question with us is, whether there be any sufficient reason for believing that attraction is produced by an emanation. For my part, I am totally at a loss to comprehend how particles streaming *from* a centre should draw a body *towards* it. The impulse, if impulse it be, is all the other way. Nor shall we find less difficulty in conceiving a conflux of particles, incessantly flowing to a centre, and carrying down all bodies along with it, that centre also itself being in a state of rapid motion through absolute space; for, by what source is the stream fed, or what becomes of the accumulation? Add to which, that it seems to imply a contrariety of properties, to suppose an ætherial fluid to *act* but not to *resist*; powerful enough to carry down bodies with great force towards a centre, yet, inconsistently with the nature of inert matter, powerless and perfectly yielding with respect to the motions which result from the projectile impulse. By calculations drawn from ancient notices of eclipses of the moon, we can prove that, if such a fluid exist at all, its resistance has had no sensible effect upon the moon's motion for two thousand five hundred years. The truth is, that, except this one circumstance of the variation of the attracting force at different distances agreeing with the variation of the spissitude, there is no reason whatever to support the hypothesis of an emanation; and, as it seems to me, almost insuperable reasons against it.[9]

(*) II. Our second proposition is, that, whilst the possible laws of variation were infinite, the *admissible* laws, or the laws compatible with the preservation of the system, lie within narrow limits. If the attracting force had varied according to any *direct* law of the distance, let it have been what it would, great destruction and confusion would have taken place. The direct simple proportion of the distance would, it is true, have produced an ellipse: but the perturbing forces would have acted with so much advantage, as to be continually changing the dimensions of

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[9] See note 12 and note 14 to this chapter; where Bishop Brinkley delivers an opinion entitled, undoubtedly, to the greatest respect, but which seems somewhat more decided than the facts as yet warrant, in favour of the etherial fluid.

the ellipse, in a manner inconsistent with our terrestrial creation. For instance; if the planet Saturn, so large and so remote, had attracted the earth, both in proportion to the quantity of matter contained in it, which it does; and also in any proportion to its distance, *i. e.* if it had pulled the harder for being the farther off (instead of the reverse of it), it would have dragged out of its course the globe which we inhabit, and have perplexed its motions, to a degree incompatible with our security, our enjoyments, and probably our existence. Of the *inverse* laws, if the centripetal force had changed as the cube of the distance, or in any higher proportion, that is (for I speak to the unlearned), if, at double the distance, the attractive force had been diminished to an eighth part, or to less than that, the consequence would have been, that the planets, if they once began to approach the sun, would have fallen into his body; if they once, though by ever so little, increased their distance from the centre, would for ever have receded from it. The laws therefore of attraction, by which a system of revolving bodies could be upholden in their motions, lie within narrow limits, compared with the possible laws. I much under-rate the restriction, when I say that, in a scale of a mile, they are confined to an inch. All direct ratios of the distance are excluded, on account of danger from perturbing forces:[10] all reciprocal ratios, except what lie beneath the cube of the distance, by the demonstrable consequence, that every the least change of distance would, under the operation of such laws, have been fatal to the repose and order of the system. We do not know, that is, we seldom reflect, how inte-

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[10] It has been objected to this statement, and the one in p. 36, that such a result would not inevitably happen from planets in any number attracting each other with forces increasing in the direct ratio of their distances, as, indeed, Sir Isaac Newton has shown (Principia, lib. i., prop. 64) how they would revolve in equal times and in elliptical orbits, (see also the 10th and 58th propositions.) In truth, all motion in elliptical orbits is connected with an increase of the force in the direct ratio of the radius vector, if the centre of the figure be the centre of forces, of which Bishop Brinkley must have been, of course, aware—(See p. 35.) But if the statement in the text be taken to include the action of other bodies and systems, on the supposition that the attraction is universal,—which, it must be remembered, is involved in the very hypothesis of its increasing with the distance,—there seems no solid objection to this part, at least, of the observation; for a rushing together of all the systems, the solar and those of the fixed stars, would be the consequence of the attraction increasing according to any power of the distance, while those systems had no motion of projection.

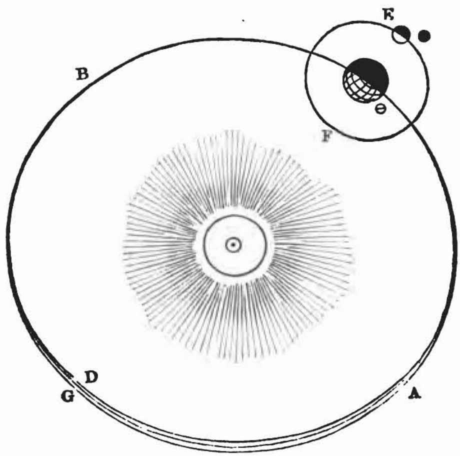
rested we are in this matter. Small irregularities may be endured; but, changes within these limits being allowed for, the permanency of our ellipse is a question of life and death to our whole sensitive world.

(*) III. That the subsisting law of attraction falls within the limits which utility requires, when these limits bear so small a proportion to the range of possibilities upon which chance might equally have cast it, is not, with any appearance of reason, to be accounted for, by any other cause than a regulation proceeding from a designing mind. But our next proposition carries the matter somewhat farther. We say, in the third place, that, out of the different laws which lie within the limits of admissible laws, the *best* is made choice of; that there are advantages in this particular law which cannot be demonstrated to belong to any other law; and, concerning some of which, it can be demonstrated that they do not belong to any other.

(*) 1. Whilst this law prevails between each particle of matter, the *united* attraction of a sphere, composed of that matter, observes the same law. This property of the law is necessary, to render it applicable to a system composed of spheres, but it is a property which belongs to no other law of attraction that is admissible. The law of variation of the united attraction is in no other case the same as the law of attraction of each particle, one case excepted, and that is of the attraction varying directly as the distance; the inconveniency of which law, in other respects, we have already noticed.

We may follow this regulation somewhat farther, and still more strikingly perceive that it proceeded from a designing mind. A law both admissible and convenient was requisite. In what way is the law of the attracting globes obtained? Astronomical observations and terrestrial experiments show that the attraction of the globes of the system is made up of the attraction of their parts; the attraction of each globe being compounded of the attractions of its parts. Now the admissible and convenient law which exists, could not be obtained in a system of bodies gravitating by the united gravitation of their parts, unless each particle of matter were attracted by a force varying by one particular law, *viz.* varying inversely as the square of the distance: for, if the action of the particles be according to any other law whatever, the admissible and convenient law, which is adopted, could not be obtained. Here then are clearly shown regulation and design. A law both admissible and convenient was to be obtained; the mode chosen for obtaining that law was by making *each* particle of matter act. After this choice was made, then further attention was to be given to each particle of matter, and one and one only particular law of action to be assigned to it. No other law would have answered the purpose intended.

(*) 2. All systems must be liable to *perturbations.* And therefore, to guard against these perturbations, or rather to guard against their running to destructive lengths, is perhaps the strongest evidence of care and foresight that can be given. Now, we are able to demonstrate of our law of attraction, what can be demonstrated of no other, and what qualifies the dangers which arise from cross but unavoidable influences; that the action of the parts of our system upon one another, will not cause permanently increasing irregularities, but merely periodical or vibratory ones; that is, they will come to a limit, and then go back again. This we can demonstrate only of a system, in which the following properties concur, *viz.* that the force shall be inversely as the square of the distance; the masses of the revolving bodies small, compared with that of the body at the centre; the orbits not much inclined to one another; and their eccentricity little. In such a system, the grand points are secure. The mean distances and periodic times, upon which depend our temperature, and the regularity of our year, are constant. The eccentricities, it is true, will still vary; but so slowly, and to so small an extent, as to produce no inconveniency from fluctuation of temperature and season. The same as to the obliquity of the planes of the orbits. For instance, the inclination of the ecliptic to the equator will never change above two degrees (out of ninety), and that will require many thousand years in performing.[11]



[11] This cut represents the oval A B, nearly circular, in which the Earth ⊖ moves round the Sun ⊙ in one of the foci—while the Moon, E, moves round the Earth in a similar curve, E F. These curves vary (as do the paths of all the planets and their satellites), becoming more and more bulged, till they bulge out by a certain quan-

It has been rightly also remarked, that, if the great planets, Jupiter and Saturn, had moved in

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tity, GD, so as to be AGB, and then the curve they describe flattens constantly, till it becomes ADB, but never more, in consequence of the four circumstances mentioned in the text.

The celebrated proposition of Laplace, respecting the eccentricities of the planetary orbits, and their deviation from a nearly circular form,—that upon which the stability of the system mainly rests,—may be comprehended by this illustration. Suppose three vessels of different burthen sail from one port to another, and take such courses, that, multiplying the tonnage of each by the square of the deviation in miles which it makes from the straight line, or shortest distance, between the two ports, and adding the three products together, the sum is at every instant of the voyage the same,—say 90—the vessels being of 10, 22½, and 90 tons burthen, respectively. It is clear that none of them can ever deviate beyond a certain distance from the straight course, for the greatest possible deviation would be 3 miles—(the square-root of the quotient of 90 divided by the tonnage of the smallest vessel,)—and this supposes neither of the other two to deviate at all; if they also had their deviations, that would make the smallest vessel's deviation so much the less. In like manner, the second vessel never could deviate more than 2, nor the largest more than 1. But these deviations would always be lessened in proportion as the other vessels deviated. If lower spheres, their influences would have had much more effect as to disturbing the planetary

we suppose the three to start from three ports in a straight line from each other, and one port to be 64, another 81, and the third 100 miles from the port of destination, and make the condition to be, that the sums of each vessel's tonnage multiplied by the square of its deviation and the products by the sums 8, 9, and 10, respectively, (the square roots of the distances of the three ports of departure,) shall be always equal to the same number, *e. g.* 90,—the case will resemble more closely the one we are illustrating; for the proposition of Laplace is, that the sum of the products of the square roots of the transverse axes of the orbits, multiplied by the squares of the eccentricities and by the masses, is always the same (*Méc. Cél.* liv. ii. c. 7 and 8; especially s. 57. 61.)

The case which we have taken, however, is only by way of illustration, and does not resemble the one in question as to particulars. Moreover, in order that all the three vessels may be able to obey the rule during each part of their course, we must suppose one of them to start from a point on one side of the port, and the same vessel, or another of them, to make a port different from the port of destination. This difficulty would be removed by supposing the condition to be, that the sums of the products should *never exceed* a certain amount.

In the case put it is clear that, practically speaking, no combination among the navigators could make the motions, than they now have. While they revolve at so great distances from the rest, they act almost

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vessels perform their voyage according to the condition unless by two of the vessels going in the straight line and the third in a line parallel to it. Nothing but a principle acting equally on the crews of all the vessels, like gravitation, or like instinct, could keep them to the terms of the rule if they were all to deviate and to vary in their deviations. But that insects should, by some such instinct, be able to perform an operation of this kind seems quite possible. Each bee acts in the construction of its cell in this way; for it keeps to the rule accurately, and it acts in perfect concert with others; at least it acts so as to produce the effect of concert.

The theorem to which we have here alluded, as well as those two similar theorems which make the mean motions and mean longitudes of the three first satellites of Jupiter, follow a certain fixed rule, the difference between thrice the motions and longitudes of the second, and the motions and longitudes of the first added to twice those of the third, being an invariable quantity; (that is, 0 in the case of the motions, and 180 degrees in the case of the longitudes,) are all deducible by strict mathematical reasoning, but from data which are not necessarily true; for these theorems depend, among other things, upon the motions of revolution throughout the system being in the same direction. Laplace has expressed an opinion, that the relation just mentioned as to Jupiter's satellites was not the same when the motion equally on the sun and on the inferior planets; which has nearly the same consequence as not acting at all upon either.

If it be said, that the planets might have been sent round the sun in exact circles, in which case, no change of distance from the centre taking place, the law of variation of the attracting power would have never come in question, one law would have served as well as another; an answer to the scheme may be drawn from the consideration of these same perturbing forces. The system retaining in other respects its present constitution, though the planets had been at first sent round in exact circular orbits, they could not have kept them:

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began, but was established by the mutual actions of these bodies, which he has shown were sufficient to establish the relation at first, as well as to maintain it afterwards. This may or it may not be; that is, it may or it may not be true that those relations were established in the course of the system's action; but no kind of argument arises from hence against the designing power, even if we admit the supposition of that great mathematician; for then it would only follow that the same principle which was appointed to preserve had also been appointed to create the relation of stability. (See *Méc. Cél.* liv. ii. c. 8, s. 66; liv. viii. c. 6, s. 15, and c. 10, s. 29. See also Mrs. Somerville's truly profound and admirable work, *Mechanism of the Heavens*, b. iv. c. 1, s. 849, *et seq.*)

and if the law of attraction had not been what it is, or at least, if the prevailing law had transgressed the limits above assigned, every evagation would have been fatal: the planet once drawn, as drawn it necessarily must have been, out of its course, would have wandered in endless error.[18]

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[18] (Note of Bishop Brinkley.) Many suppose attraction an emanation, and the law of attraction (the inverse square of the distance) which exists, to be actually *necessary* and deducible from *equal* quantities of the attractive force being spread over each spherical surface surrounding the attractive centre. If this were so, all attracting matter must act according to the same law. This is not the case in many instances that might be adduced. The attraction by which particles of matter adhere together is obviously not of this nature. Chemical action furnishes many exceptions to this law. It may, indeed, be said that a polarizing power may be joined to an attractive force acting as abovementioned. We know very imperfectly, or rather nothing, of the nature of this polarization; but we know it is not extended to the actions of the sun and planetary masses on each other. Why was it not extended to these? The simple answer is, that it would not only have been useless, but it would have interfered with the purposes for which these bodies were designed. Thus these great bodies are moved by laws of the utmost simplicity, while their component parts act on each other by a combination of forces of various kinds; which forces appear to act at small dis-

(*) V. What we have seen in the law of the centripetal force, *viz.* a choice guided by views of utility, and a choice of one law out of thousands which might equally have taken place, we see no less in the *figures* of the planetary orbits. It was not enough to fix the law of the centripetal force, though by the wisest choice; for, even under that law, it was still competent to the planets to have moved in paths possessing so great a degree of eccentricity, as, in the course of every revolution, to be brought very near to the sun, and carried away to immense distances from him. The comets actually move in orbits of this sort: and, had the planets done so, instead of going round in orbits nearly circular, the change from one extremity of temperature to another must, in ours at least, have destroyed every animal and plant upon its surface. Now the distance from the centre at which a planet sets off, and the absolute force of attraction at that distance, being fixed, the figure of its orbit, its being a circle, or nearer to, or farther off from a circle, *viz.* a rounder or a longer oval, depends upon two things, the velocity with which, and the

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tances only, while the forces on which depend the welfare and preservation of our earth and the planets, act through a vast extent of space, and by one simple and uniform law, in which there is no conflicting interference of other actions.

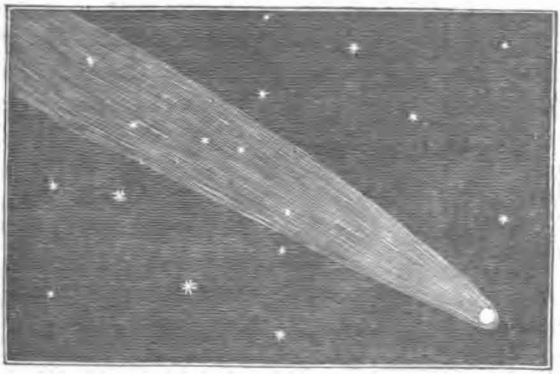
direction in which, the planet is projected. And these, in order to produce a right result, must be both brought within certain narrow limits. One, and only one, velocity, united with one, and only one, direction, will produce a perfect circle. And the velocity must be near to this velocity, and the direction also near to this direction, to produce orbits, such as the planetary orbits are, nearly circular; that is, ellipses with small eccentricities. The velocity and the direction must *both* be right. If the velocity be wrong, no direction will cure the error; if the direction be in any considerable degree oblique, no velocity will produce the orbit required. Take, for example, the attraction of gravity at the surface of the earth. The force of that attraction being what it is, out of all the degrees of velocity, swift and slow, with which a ball might be shot off, none would answer the purpose of which we are speaking, but what was nearly that of five miles in a second. If it were less than that, the body would not get round at all, but would come to the ground; if it were in any considerable degree more than that, the body would take one of those eccentric courses, those long ellipses, of which we have noticed the inconveniency. If the velocity reached the rate of seven miles in a second, or went beyond that, the ball would fly off from the earth, and never be heard of more. In like manner with respect to the *di-*

rection; out of the innumerable angles in which the ball might be sent off (I mean angles formed with a line drawn in the centre), none would serve but what was nearly a right one: out of the various directions in which the cannon might be pointed, upwards and downwards, every one would fail, but what was exactly or nearly horizontal. The same thing holds true of the planets: of our own amongst the rest. We are entitled therefore to ask, and to urge the question, Why did the projectile velocity and projectile direction of the earth happen to be nearly those which would retain it in a *circular* form? Why not one of the infinite number of velocities, one of the infinite number of directions, which would have made it approach much nearer to, or recede much farther from, the sun?

The planets going round, all in the same direction, and all nearly in the same plane, afforded to Buffon a ground for asserting, that they had all been shivered from the sun by the same stroke of a comet, and by that stroke projected into their present orbits. Now, beside that this is to attribute to chance the fortunate concurrence of velocity and direction which we have been here noticing, the hypothesis, as I apprehend, is inconsistent with the physical laws by which the heavenly motions are governed. If the planets were struck off from the surface of the sun, they would return to the surface of the sun again. Nor will this difficulty be got rid of, by supposing that the same violent blow which shattered the sun's surface, and separated large fragments from it, pushed the sun himself out of his place; for, the consequence of this would be that the sun and system of shattered fragments would have a progressive motion, which, indeed, may possibly be the case with our system; but then each fragment would, in every revolution, return to the surface of the sun again. The hypothesis is also contradicted by the vast difference which subsists between the *diameters* of the planetary orbits. The distance of Saturn from the sun (to say nothing of the Georgium Sidus) is nearly five-and-twenty times that of Mercury; a disparity, which it seems impossible to reconcile with Buffon's scheme. Bodies starting from the same place, with whatever difference of direction or velocity they set off, could not have been found at these different distances from the centre, still retaining their nearly circular orbits. They must have been carried to their proper distances, before they were projected*.

* "If we suppose the matter of the system to be accumulated in the centre by its gravity, no mechanical principles, with the assistance of this power of gravity, could separate the vast mass into such parts as the sun and planets; and, after carrying them

To conclude: In astronomy, the great thing is to raise the imagination to the subject, and that oftentimes in opposition to the impression made upon the senses. An illusion, for example, must be gotten over arising from the distance at which we view the heavenly bodies, *viz.* the apparent *slowness* of their motions.[18] The moon shall take



[18] This cut represents the comet of 1811, the fixed stars being seen through its tail, which extended

to their different distances, project them in their several directions, preserving still the quality of action and re-action, or the state of the centre of gravity of the system. Such an exquisite structure of things could only arise from the contrivance and powerful influences of an intelligent, free, and most potent agent. The same powers, therefore, which, at present, govern the material universe, and conduct its various motions, are *very different* from those which were necessary to have produced it from nothing, or to have disposed it in the admirable form in which it now proceeds."—*Maclaurin's Account of Newton's Philosophy*, p. 407. ed. 3.

some hours in getting half a yard from a star which it touched. A motion so deliberate we may

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123,000,000 of miles. The period of its revolution is calculated at above 3,300 years. The great comet of 1680 was calculated by Sir Isaac Newton to have a tail of 80,000,000 of miles, immediately after its perihelion, a periodic time of 575 years, and a velocity, when nearest the sun, of 880,000 miles in an hour. Its orbit is so much elongated that its greatest distance from the sun is estimated at near 3,000 millions of miles, and its least at only 150,000 miles. Halley's comet, which appeared in 1682, 1759, and 1835,—probably also in 1531 and 1607,—has a mean distance from the sun of 1,705 millions of miles, the earth's mean distance being 96,000,000; but while the earth's orbit is so nearly circular that the planet's greatest distance is only a thirtieth part more than its smallest, this comet's aphelion (or greatest) distance is above 3,355 millions, and its perihelion (or least) distance only 55 millions, or sixty-one times less. So the transverse (or longer) axis of its orbit is four times the length of the conjugate (or shorter) axis; whereas the two axes of the earth's orbit differ by only a 7000th part from one another. Most of the planetary orbits are nearly circular also,—that of Pallas being the most elongated, and in the proportion of only 5 to 3. But the orbits of the comets have every variety of shape as well as size, and their motion the greatest difference in velocity; yet they appear all to follow the same general laws,—and these the same by which the planetary motions are governed.

think easily guided. But what is the fact? The moon, in fact, is, all this while, driving through the heavens at the rate of considerably more than two thousand miles in an hour; which is more than double of that with which a ball is shot off from the mouth of a cannon. Yet is this prodigious rapidity as much under government, as if the planet proceeded ever so slowly, or were conducted in its course inch by inch. It is also difficult to bring the imagination to conceive (what yet, to judge tolerably of the matter, it is necessary to conceive) how *loose*, if we may so express it, the heavenly bodies are. Enormous globes, held by nothing, confined by nothing, are turned into free and boundless space, each to seek its course by the virtue of an invisible principle; but a principle, one, common, and the same in all, and ascertainable. To preserve such bodies from being lost, from running together in heaps, from hindering and distracting one another's motions, in a degree inconsistent with any continuing order; *h. e.* to cause them to form planetary systems, systems that, when formed, can be upheld, and, most especially, systems accommodated to the organised and sensitive natures, which the planets sustain, as we know to be the case, where alone we can know what the case is, upon our earth: all this requires an intelligent interposition, because it can be demonstrated concerning it, that it requires an adjustment of force, distance, direction, and velocity, out of the reach of chance to have produced; an adjustment, in its view to utility, similar to that which we see in ten thousand subjects of nature which are nearer to us, but in power, and in the extent of space through which that power is exerted, stupendous.[14]

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[14] (Note of Bishop Brinkley. See Note 9.) Since the publication of Dr. Paley's 'Natural Theology' it has been ascertained that a resisting medium is actually diffused through our system. But it is of so rare a nature, that the planets will not be affected by it for an immense period. The existence of this resisting medium has been ascertained by the successive revolutions of the small comet, the orbit of which was first accurately computed by M. Encke, and its identity verified on several successive returns. We had before a knowledge of the weak action of comets on the planets, and of the consequent smallness of their masses. It was also inferred that they were bodies of small density, and consequently would be more sensibly affected in their motions through a resisting medium. This comet was found in 1795 by Miss Herschel, and observed also by her brother. His account of it, when considered with reference to what has since been ascertained as to the resistance it meets with in its course, is remarkable (vide Phil. Trans. 1796, p. 133) :—" The comet is now centrically on a small star. It is a small telescopic star of

But many of the heavenly bodies, as the sun and fixed stars, are *stationary*. Their rest must

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about the eleventh or twelfth magnitude, and is double, very unequal; with a power of 287 I can see the smallest of the two stars perfectly well. This shows how little density there is in the comet, which is evidently nothing but what may be called a collection of vapours." This comet is also remarkable for the shortness of its period, about three and a half years, not receding so far from the sun as the planet Jupiter. In the solar system the difference between the two classes of bodies which revolve round the sun, and are retained in their orbits by the solar action, is most marked and distinct. Comets so numerous serve for purposes entirely unknown to us. Indeed, hitherto no probable conjecture has been formed as to those purposes. That they are not the habitations of beings similar to those which exist on the earth is nearly certain. The earth and planets appear wisely adapted, in a variety of ways, for the convenience and preservation of animals and vegetables. The comets are not so adapted. In one case orbits nearly circular were required, in the other they were not required.

There is another circumstance in which design appears strongly marked, although we cannot explain the purport of it. The planets appear to be placed at distances from the sun, according to a certain law. This was remarked by Professor Bode, and that the law was not complete unless a planet existed between Mars and Jupiter. The new planets were afterwards discovered, each of them be the effect of an absence or of an equilibrium of attractions. It proves also, that a projectile impulse was originally given to some of the heavenly

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circulating between Jupiter and Mars, at a distance from the sun, conformable to the conjectured law*. The cause of more than one planet being found at this distance has, with some degree of probability, been derived from the hypothesis, that a large planet has been shattered into fragments, which fragments are the planets Ceres, Vesta, Pallas, and Juno. That wonderful changes occasionally offer themselves to our notice, as wonderful as the destruction of a planet, is exemplified in the appearance and disappearance of a fixed star. A star suddenly appeared in 1571 of a degree of splendour exceeding all the other fixed stars. It was seen during sixteen months, and continually diminished in brightness till it disappeared. All the circumstances of it are well attested by many astronomers, and others. It remained fixed in one spot of the heavens without changing its place among the other stars by any perceptible quantity. Although astronomical instruments at that time did not admit of a degree of precision to be compared with those of the present time, yet the observations made on it by several astronomers fully suffice to show that its distance from us must have been at least between 3000 and 4000 times that of the sun from the earth, or 300,000 millions of miles.

* See first note to Chap. xxv. *infra*.

bodies, and not to others. But further: if attraction act at all distances, there can only be one quiescent centre of gravity in the universe; and all bodies whatever must be approaching this centre or revolving round it. According to the first of these suppositions, if the duration of the world had been long enough to allow of it, all its parts, all the great bodies of which it is composed, must have been gathered together in a heap round this point. No changes however which have been observed, afford us the smallest reason for believing, that either the one supposition or the other is true: and then it will follow, that attraction itself is controlled or suspended by a superior agent; that there is a power above the highest of the powers of material nature; a will which restrains and circumscribes the operations of the most extensive*.

* It must here, however, be stated, that many astronomers deny that any of the heavenly bodies are absolutely stationary. Some of the brightest of the fixed stars have certainly small motions; and of the rest the distance is too great, and the intervals of our observation too short, to enable us to pronounce with certainty that they may not have the same. The motions in the fixed stars which have been observed, are considered either as proper to each of them, or as compounded of the motion of our system, and of motions proper to each star. By a comparison of these motions, a motion in our system is supposed to be discovered. By continuing this analogy to other, and to all systems, it is possible to suppose that attraction is unlimited, and that the whole material universe is revolving round some fixed point within its containing sphere or space.—*Note of the Author.*

CHAPTER XXIII.

OF THE PERSONALITY OF THE DEITY.

CONTRIVANCE, if established, appears to me to prove every thing which we wish to prove. Amongst other things, it proves the *personality* of the Deity, as distinguished from what is sometimes called nature, sometimes called a principle: which terms, in the mouths of those who use them philosophically, seem to be intended, to admit and to express an efficacy, but to exclude and to deny a personal agent. Now that which can contrive, which can design, must be a person. These capacities constitute personality, for they imply consciousness and thought. They require that which can perceive an end or purpose; as well as the power of providing means, and directing them to their end*. They require a centre in which perceptions unite, and from which volitions flow; which is mind. The acts of a mind prove the existence of a mind; and in whatever a mind resides, is a person. The seat of intellect is a person. We have no authority to limit the properties of

* Priestley's Letters to a Philosophical Unbeliever, p. 153, ed. 2.

mind to any particular corporeal form, or to any particular circumscription of space. These properties subsist, in created nature, under a great variety of sensible forms. Also every animated being has its *sensorium;* that is, a certain portion of space, within which perception and volition are exerted. This sphere may be enlarged to an indefinite extent; may comprehend the universe; and, being so imagined, may serve to furnish us with as good a notion, as we are capable of forming, of the *immensity* of the Divine Nature, *i. e.* of a divine Being, infinite, as well in essence as in power; yet nevertheless a person.

"No man hath seen God at any time." And this, I believe, makes the great difficulty. Now it is a difficulty which chiefly arises from our not duly estimating the state of our faculties. The Deity, it is true, is the object of none of our senses: but reflect what limited capacities animal senses are. Many animals seem to have but one sense, or perhaps two at the most; touch and taste. Ought such an animal to conclude against the existence of odours, sounds, and colours? To another species is given the sense of smelling. This is an advance in the knowledge of the powers and properties of nature: but, if this favoured animal should infer from its superiority over the class last described, that it perceived everything which was perceptible in nature, it is known to us, though perhaps not suspected by the animal itself, that it proceeded upon a false and presumptuous estimate of its faculties. To another is added the sense of hearing; which lets in a class of sensations entirely unconceived by the animal before spoken of; not only distinct, but remote from any which *it* had ever experienced, and greatly superior to them. Yet this last animal has no more ground for believing that its senses comprehend all things, and all properties of things, which exist, than might have been claimed by the tribes of animals beneath it; for we know that it is still possible to possess another sense, that of sight, which shall disclose to the percipient a new world. This fifth sense makes the animal what the human animal is: but to infer that possibility stops here; that either this fifth sense is the last sense, or that the five comprehend all existence,—is just as unwarrantable a conclusion as that which might have been made by any of the different species which possessed fewer, or even by that, if such there be, which possessed only one. The conclusion of the one-sense animal, and the conclusion of the five-sense animal, stand upon the same authority. There may be more and other senses than those which we have. There may be senses suited to the perception of the powers, properties, and substance, of spirits. These may belong to higher orders of rational agents; for there is not the smallest reason for supposing that we are the highest, or that the scale of creation stops with us.

The great *energies* of nature are known to us only by their effects. The substances which produce them are as much concealed from our senses as the Divine essence itself. *Gravitation*, though constantly present, though constantly exerting its influence, though everywhere around us, near us, and within us; though diffused throughout all space, and penetrating the texture of all bodies with which we are acquainted, depends, if upon a fluid, upon a fluid which, though both powerful and universal in its operation, is no object of sense to us; if upon any other kind of substance or action, upon a substance and action from which *we* receive no distinguishable impressions. Is it then to be wondered at that it should, in some measure, be the same with the Divine nature?

Of this, however, we are certain, that whatever the Deity be, neither the *universe*, nor any part of it which we see, can be He. The universe itself is merely a collective name: its parts are all which are real; or which are *things*. Now inert matter is out of the question; and organised substances include marks of contrivance. But whatever includes marks of contrivance, whatever, in its constitution, testifies design, necessarily carries us to something beyond itself, to some other being, to a designer prior to, and out of itself. No animal, for instance, can have contrived its own limbs and senses: can have been the author to itself of the design with which they were constructed. That supposition involves all the absurdity of self-creation, *i. e.* of acting without existing. Nothing can be God, which is ordered by a wisdom and a will, which itself is void of; which is indebted for any of its properties to contrivance *ab extra*. The *not* having that in his nature which requires the exertion of another prior being (which property is sometimes called self-sufficiency, and sometimes self-comprehension) appertains to the Deity, as his essential distinction, and removes his nature from that of all things which we see. Which consideration contains the answer to a question that has sometimes been asked, namely, Why, since something or other must have existed from eternity, may not the present universe be that something? The contrivance perceived in it proves that to be impossible. Nothing contrived can, in a strict and proper sense, be eternal, forasmuch as the contriver must have existed before the contrivance.

Wherever we see marks of contrivance, we are led for its cause to an *intelligent* author. And this transition of the understanding is founded upon uniform experience. We see intelligence constantly contriving; that is, we see intelligence constantly producing effects, marked and distinguished by certain properties; not certain particular properties, but by a kind and class of properties, such as relation to an end, relation of parts to one another, and to a common purpose. We see, wherever we are witnesses to the actual formation of things, nothing except intelligence producing effects so marked and distinguished. Furnished with this experience, we view the productions of nature. We observe *them* also marked and distinguished in the same manner. We wish to account for their origin. Our experience suggests a cause perfectly adequate to this account. No experience, no single instance or example, can be offered in favour of any other. In this cause, therefore, we ought to rest; in this cause the common sense of mankind has, in fact, rested, because it agrees with that, which, in all cases, is the foundation of knowledge,—the undeviating course of their experience. The reasoning is the same as that, by which we conclude any ancient appearances to have been the effects of volcanoes or inundations; namely, because they resemble the effects which fire and water produce before our eyes; and because we have never known these effects to result from any other operation. And this resemblance may subsist in so many circumstances, as not to leave us under the smallest doubt in forming our opinion. Men are not deceived by this reasoning: for whenever it happens, as it sometimes does happen, that the truth comes to be known by direct information, it turns out to be what was expected. In like manner, and upon the same foundation, (which in truth is that of experience,) we conclude that the works of nature proceed from intelligence and design; because, in the properties of relation to a purpose, subserviency to a use, they resemble what intelligence and design are constantly producing, and what nothing except intelligence and design ever produce at all. Of every argument, which would raise a question as to the safety of this reasoning, it may be observed, that if such argument be listened to, it leads to the inference, not only that the present order of nature is insufficient to prove the existence of an intelligent Creator, but that no imaginable order would be sufficient to prove it; that *no* contrivance, were it ever so mechanical, ever so precise, ever so clear, ever so perfectly like those which we ourselves employ, would support this conclusion—a doctrine, to which I conceive no sound mind can assent.

The force, however, of the reasoning is sometimes sunk by our taking up with mere names. We have already noticed,* and we must here notice again, the misapplication of the term "law," and the mistake concerning the idea which that term expresses in physics, whenever such idea is made to take the place of power, and still more of an intelligent power, and, as such, to be assigned for the cause of any thing, or of any property of anything, that exists. This is what we are secretly apt to do, when we speak of organised bodies (plants for instance, or animals) owing their production, their form, their growth, their qualities, their beauty, their use, to any law or laws of nature; and when we are contented to sit down with that answer to our inquiries concerning them. I say once more, that it is a perversion of language to assign any law, as the efficient, operative cause of any thing. A law pre-supposes an agent, for it is only the mode according to which an agent proceeds; it implies a power, for it is the order according to which

* Ch. I. sect. vii.

that power acts. Without this agent, without this power, which are both distinct from itself, the "law" does nothing; is nothing.

What has been said concerning "law," holds true of *mechanism*. Mechanism is not itself power. Mechanism, without power, can do nothing. Let a watch be contrived and constructed ever so ingeniously; be its parts ever so many, ever so complicated, ever so finely wrought or artificially put together, it cannot *go* without a weight or spring, *i. e.* without a force independent of, and ulterior to, its mechanism. The spring acting at the centre, will produce different motions and different results, according to the variety of the intermediate mechanism. One and the self-same spring, acting in one and the same manner, *viz.* by simply expanding itself, may be the cause of a hundred different and all useful movements, if a hundred different and well-devised sets of wheels be placed between it and the final effect: *e. g.* may point out the hour of the day, the day of the month, the age of the moon, the position of the planets, the cycle of the years, and many other serviceable notices; and these movements may fulfil their purposes with more or less perfection, according as the mechanism is better or worse contrived, or better or worse executed, or in a better or worse state of repair: *but in all cases it* *is necessary that the spring act at the centre.* The course of our reasoning upon such a subject would be this: By inspecting the watch, even when standing still, we get a proof of contrivance, and of a contriving mind, having been employed about it. In the form and obvious relation of its parts, we see enough to convince us of this. If we pull the works in pieces, for the purpose of a closer examination, we are still more fully convinced. But, when we see the watch *going*, we see proof of another point, *viz.* that there is a power somewhere, and somehow or other applied to it; a power in action;—that there is more in the subject than the mere wheels of the machine;—that there is a secret spring, or a gravitating plummet;—in a word, that there is force, and energy, as well as mechanism.

So, then, the watch in motion establishes to the observer two conclusions: One,—that thought, contrivance, and design, have been employed in the forming, proportioning, and arranging of its parts; and that whoever or wherever he be, or were, such a contriver there is, or was: The other,—that force or power, distinct from mechanism, is, at this present time, acting upon it. If I saw a hand-mill even at rest, I should see contrivance: but if I saw it grinding, I should be assured that a hand was at the windlass, though in another room. It is the same in nature. In the works of nature we trace mechanism; and this alone proves contrivance: but living, active, moving, productive nature, proves also the exertion of a power at the centre: for, wherever the power resides may be denominated the centre.

The intervention and disposition of what are called "*second causes*" fall under the same observation. This disposition is or is not mechanism, according as we can or cannot trace it by our senses and means of examination. That is all the difference there is; and it is a difference which respects our faculties, not the things themselves. Now where the order of second causes is mechanical, what is here said of mechanism strictly applies to it. But it would be always mechanism (natural chemistry, for instance would be mechanism), if our senses were acute enough to descry it. Neither mechanism, therefore, in the works of nature, nor the intervention of what are called second causes (for I think that they are the same thing), excuses the necessity of an agent distinct from both.

If, in tracing these causes, it be said that we find certain general properties of matter which have nothing in them that bespeaks intelligence, I answer, that still the *managing* of these properties, the pointing and directing them to the uses which we see made of them, demands intelligence in the highest degree. For example: suppose animal secretions to be elective attractions, and that such and such attractions universally belong to such and such substances—in all which there is no intellect concerned; still the choice and collocation of these substances, the fixing upon right substances, and disposing them in right places, must be an act of intelligence. What mischief would follow were there a single transposition of the secretory organs; a single mistake in arranging the glands which compose them!

There may be many second causes, and many courses of second causes, one behind another, between what we observe of nature, and the Deity: but there must be intelligence somewhere: there must be more in nature than what we see; and, amongst the things unseen, there must be an intelligent, designing author. The philosopher beholds with astonishment the production of things around him. Unconscious particles of matter take their stations, and severally range themselves in an order, so as to become collectively plants or animals, *i. e.* organised bodies, with parts bearing strict and evident relation to one another, and to the utility of the whole: and it should seem that these particles could not move in any other way than as they do; for they testify not the smallest sign of choice, or liberty, or discretion. There may be particular intelligent beings, guiding these motions in each case: or they may be the result of trains of mechanical dispositions, fixed beforehand by an intelligent appointment, and kept in action by a power at the centre. But, in either case, there must be intelligence.

The minds of most men are fond of what they call a *principle*, and of the appearance of simplicity, in accounting for phænomena. Yet this principle, this simplicity, resides merely in the *name*; which name, after all, comprises, perhaps, under it a diversified, multifarious, or progressive operation, distinguishable into parts. The power in organised bodies, of producing bodies like themselves, is one of these principles. Give a philosopher this, and he can get on. But he does not reflect what this mode of production, this principle (if such he choose to call it) requires; how much it presupposes; what an apparatus of instruments, some of which are strictly mechanical, is necessary to its success; what a train it includes of operations and changes, one succeeding another, one related to another, one ministering to another; all advancing, by intermediate, and, frequently, by sensible steps, to their ultimate result! Yet, because the whole of this complicated action is wrapped up in a single term, *generation,* we are to set it down as an elementary principle; and to suppose, that when we have resolved the things which we see into this principle, we have sufficiently accounted for their origin, without the necessity of a designing, intelligent Creator. The truth is, generation is not a principle but a *process.* We might as well call the casting of metals a principle; we might, so far as appears to me, as well call spinning and weaving principles: and then, referring the texture of cloths, the fabric of muslins and calicoes, the patterns of diapers and damasks, to these, as principles, pretend to dispense with intention, thought, and contrivance, on the part of the artist; or to dispense, indeed, with the necessity of any artist at all, either in the manufacturing of the article, or in the fabrication of the machinery by which the manufacture was carried on.

And, after all, how, or in what sense is it true, that animals produce their *like?* A butterfly, with a proboscis instead of a mouth, with four wings and six legs, produces a hairy caterpillar, with jaws and teeth, and fourteen feet. A frog produces a tadpole. A black beetle, with gauze wings, and a crusty covering, produces a white, smooth, soft worm; an ephemeron fly, a cod-bait maggot. These, by a progress through different stages of life, and action, and enjoyment (and, in each state, provided with implements and organs appropriated to the temporary nature which they bear), arrive at last at the form and fashion of the parent animal. But all this is process, not principle; and proves, moreover, that the property of animated bodies, of producing their like, belongs to them, not as a primordial property, not by any blind necessity in the nature of things, but as the effect of œconomy, wisdom, and design; because the property itself assumes diversities, and submits to deviations dictated by intelligible utilities, and serving distinct purposes of animal happiness.

The opinion, which would consider "generation" as a *principle* in nature; and which would assign this principle as the cause, or endeavour to satisfy our minds with such a cause, of the existence of organised bodies; is confuted, in my judgment, not only by every mark of contrivance discoverable in those bodies, for which it gives us no contriver, offers no account whatever; but also by the further consideration, that things generated possess a clear relation to things *not* generated. If it were merely one part of a generated body bearing a relation to another part of the same body; as the mouth of an animal to the throat, the throat to the stomach, the stomach to the intestines, those to the recruiting of the blood, and, by means of the blood, to the nourishment of the whole frame: or if it were only one generated body bearing a relation to another generated body; as the sexes of the same species to each other, animals of prey to their prey, herbivorous and granivorous animals to the plants or seeds upon which they feed; it might be contended, that the whole of this correspondency was attributable to generation, the common origin from which these substances proceeded. But what shall we say to agreements which exist between things generated and things *not generated?* Can it be doubted, was it ever doubted, but that the *lungs* of animals bear a relation to the *air*, as a permanently elastic fluid? They act in it and by it; they cannot act without it. Now, if generation produced the animal, it did not produce the air: yet their properties correspond. The *eye* is made for *light*, and light for the eye. The eye would be of no use without light, and light perhaps of little without eyes; yet one is produced by generation, the other not. The *ear* depends upon *undulations* of air. Here are two sets of motions; first, of the pulses of the air; secondly, of the drum, bones, and nerves of the ear; sets of motions bearing an evident reference to each other: yet the one, and the apparatus for the one, produced by the intervention of generation; the other altogether independent of it.

If it be said, that the air, the light, the elements, the world itself, is *generated;* I answer, that I do not comprehend the proposition. If the term mean any thing similar to what it means when applied to plants or animals, the proposition is certainly without proof: and, I think, draws as near to absurdity as any proposition can do, which does not include a contradiction in its terms. I am at a loss to conceive how the formation of the world can be compared to the generation of an animal. If the term generation signify something quite different from what it signifies on ordinary occasions, it may, by the same latitude, signify any thing. In which case, a word or phrase taken from the language of Otaheite would convey as much theory concerning the origin of the universe, as it does to talk of its being generated.

We know a cause (intelligence) adequate to the appearances which we wish to account for: we have this cause continually producing similar appearances: yet rejecting this cause, the sufficiency of which we know, and the action of which is constantly before our eyes, we are invited to resort to suppositions destitute of a single fact for their support, and confirmed by no analogy with which we are acquainted. Were it necessary to inquire into the *motives* of men's opinions, I mean their motives separate from their arguments; I should almost suspect, that, because the proof of a Deity drawn from the constitution of nature is not only popular but vulgar (which may arise from the cogency of the proof, and be indeed its highest recommendation), and because it is a species almost of *puerility* to take up with it; for these reasons, minds, which are habitually in search of invention and originality, feel a resistless inclination to strike off into other solutions and other expositions. The truth is, that many minds are not so indisposed to any thing which can be offered to them, as they are to the *flatness* of being content with common reasons: and, what is most to be lamented, minds conscious of superiority are the most liable to this repugnancy.

The "suppositions" here alluded to all agree in one character: they all endeavour to dispense with the necessity in nature of a particular, personal intelligence; that is to say, with the exertion of an intending, contriving mind, in the structure and formation of the organised constitutions which the world contains. They would resolve all productions into *unconscious* energies, of a like kind, in that respect, with attraction, magnetism, electricity, &c.; without any thing further.

In this, the old system of atheism and the new agree. And I much doubt whether the new schemes have advanced any thing upon the old, or done more than changed the terms of the nomenclature. For instance, I could never see the difference between the antiquated system of atoms, and Buffon's organic molecules. This philosopher, having made a planet by knocking off from the sun a piece of melted glass, in consequence of the stroke of a comet; and having set it in motion, by the same stroke, both round its own axis and the sun; finds his next difficulty to be, how to bring plants and animals upon it. In order to solve this difficulty, we are to suppose the universe replenished with particles, endowed with life, but without organisation or senses of their own; and endowed also with a tendency to marshal themselves into organised forms. The concourse of these particles, by virtue of this tendency, but without intelligence, will, or direction, (for I do not find that any of these qualities are ascribed to them,) has produced the living forms which we now see.

Very few of the conjectures, which philosophers hazard upon these subjects, have more of pretension in them, than the challenging you to show the direct impossibility of the hypothesis. In the present example, there seemed to be a positive objection to the whole scheme upon the very face of it; which was that, if the case were as here represented, *new* combinations ought to be perpetually taking place; new plants and animals, or organised bodies which were neither, ought to be starting up before our eyes every day. For this, however, our philosopher has an answer. Whilst so many forms of plants and animals are already in existence, and, consequently, so many "internal moulds," as he calls them, are prepared and at hand, the organic particles run into these moulds, and are employed in supplying an accession of substance to them, as well for their growth, as for their propagation. By which means, things keep their ancient course. But, says the same philosopher, should any general loss or destruction of the present constitution of organised bodies take place, the particles, for want of "moulds" into which they might enter, would run into different combinations, and replenish the waste with new species of organised substances.

Is there any history to countenance this notion? Is it known that any destruction has been so repaired? any desert thus re-peopled?

So far as I remember, the only natural appearance mentioned by our author, by way of fact whereon to build his hypothesis, is the formation of *worms* in the intestines of animals, which is here ascribed to the coalition of superabundant organic particles, floating about in the first passages; and which have combined themselves into these simple animal forms, for want of internal moulds, or of vacancies in those moulds, into which they might be received. The thing referred to is rather a species of facts, than a single fact; as some other cases may, with equal reason, be included under it. But to make it a fact at all, or, in any sort, applicable to the question, we must begin with asserting an *equivocal* generation, contrary to analogy, and without necessity: contrary to an analogy, which accompanies us to the very limits of our knowledge or inquiries; for wherever, either in plants or animals, we are able to examine the subject, we find procreation from a parent form: without necessity; for I apprehend that it is seldom difficult to suggest methods by which the eggs, or spawn, or yet invisible rudiments of these vermin, may have obtained a passage into the cavities in which they are found*. Add to this, that their *constancy to their species*, which, I believe, is as regular in these as in the other vermes, decides the question against our philosopher, if, in truth, any question remained upon the subject.

Lastly; these wonder-working instruments,

* I trust I may be excused for not citing, as another fact which is to confirm the hypothesis, a grave assertion of this writer, that the branches of trees upon which the stag feeds break out again in his horns. Such *facts* merit no discussion.—(*Note of the Author.*)

these "internal moulds," what are they after all? what, when examined, but a name without signification; unintelligible, if not self-contradictory; at the best, differing in nothing from the "essential forms" of the Greek philosophy? One short sentence of Buffon's work exhibits his scheme as follows: "When this nutritious and prolific matter, which is diffused throughout all nature, passes through the *internal mould* of an animal or vegetable, and finds a proper matrix, or receptacle, it gives rise to an animal or vegetable of the same species." Does any reader annex a meaning to the expression "internal mould," in this sentence? Ought it then to be said, that, though we have little notion of an internal mould, we have not much more of a designing mind? The very contrary of this assertion is the truth. When we speak of an artificer or an architect, we talk of what is comprehensible to our understanding, and familiar to our experience. We use no other terms, than what refer us for their meaning to our consciousness and observation; what express the constant objects of both: whereas names like that we have mentioned refer us to nothing; excite no idea; convey a sound to the ear, but I think do no more.

Another system, which has lately been brought forward, and with much ingenuity, is that of *ap-*

petencies. The principle, and the short account of the theory, is this: Pieces of soft, ductile, matter, being endued with propensities or appetencies for particular actions, would, by continual endeavours, carried on through a long series of generations, work themselves gradually into suitable forms; and, at length, acquire, though perhaps by obscure and almost imperceptible improvements, an organisation fitted to the action which their respective propensities led them to exert. A piece of animated matter, for example, that was endued with a propensity to *fly*, though ever so shapeless, though no other we will suppose than a round ball to begin with, would, in a course of ages, if not in a million of years, perhaps in a hundred millions of years (for our theorists, having eternity to dispose of, are never sparing in time), acquire *wings*. The same tendency to loco-motion in an aquatic animal, or rather in an animated lump, which might happen to be surrounded by water, would end in the production of *fins;* in a living substance, confined to the solid earth, would put out *legs* and *feet;* or, if it took a different turn, would break the body into ringlets, and conclude by *crawling* upon the ground.

Although I have introduced the mention of this theory into this place, I am unwilling to give to it the name of an *atheistic* scheme, for two reasons:

first, because, so far as I am able to understand it, the original propensities and the numberless varieties of them (so different, in this respect, from the laws of mechanical nature, which are few and simple), are, in the plan itself, attributed to the ordination and appointment of an intelligent and designing Creator: secondly, because, likewise, that large postulatum, which is all along assumed and presupposed, the faculty in living bodies of producing other bodies organised like them selves, seems to be referred to the same cause; at least is not attempted to be accounted for by any other. In one important respect, however, the theory before us coincides with atheistic systems, *viz.* in that, in the formation of plants and animals, in the structure and use of their parts, it does away final causes.[15] Instead of the parts of a

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[15] In one sense this doctrine (if it deserve the name) of appetencies can hardly be said to supersede final causes. For suppose the *conatus* or appetency to have formed an eye, such as we now have it, and constructed as we know it to be, all its uses continue; it is calculated to perform the office required,—to supply that, the desire of supplying which is supposed to have produced it. Stating that desire caused the production appears only to be a covert and somewhat absurd mode of stating the doctrine of final causes.

plant or animal, or the particular structure of the parts, having been intended for the action or the use to which we see them applied; according to this theory, they have themselves grown out of that action, sprung from that use. The theory therefore dispenses with that which we insist upon, the necessity, in each particular case, of an intelligent, designing mind, for the contriving and determining of the forms which organised bodies bear. Give our philosopher these appetencies; give him a portion of living irritable matter (a nerve, or the clipping of a nerve), to work upon: give also to his incipient or progressive forms the power, in every stage, of their alteration, of propagating their like; and, if he is to be believed, he could replenish the world with all the vegetable and animal productions which we at present see in it.

The scheme under consideration is open to the same objection with other conjectures of a similar tendency, *viz.* a total defect of evidence. No changes, like those which the theory requires, have ever been observed. All the changes in Ovid's Metamorphoses might have been effected by these appetencies, if the theory were true; yet not an example, nor the pretence of an example, is offered of a single change being known to have taken place. Nor is the order of generation obedient to the principle upon which this theory is built. The mammæ* of the male have not vanished by inusitation; *nec curtorum, per multa sæcula, Judæorum propagini deest præputium.* It is easy to say, and it has been said, that the alterative process is too slow to be perceived; that it has been carried on through tracts of immeasurable time; and that the present order of things is the result of a graduation, of which no human records can trace the steps. It is easy to say this; and yet it is still true, that the hypothesis remains destitute of evidence.

The *analogies* which have been alleged are of the following kind: The *bunch* of a camel is said to be no other than the effect of carrying burdens; a service in which the species has been employed from the most ancient times of the world. The

* I confess myself totally at a loss to guess at the reason, either final or efficient, for this part of the animal frame: unless there be some foundation for an opinion, of which I draw the hint from a paper of Mr. Everard Home (Phil. Transact. 1799, Pt. 2), viz. that the mammæ of the fœtus may be formed before the sex is determined.[16]—(*Note of the Author.*)

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[16] The paper alluded to is upon Hermaphrodites, in vol. lxxxix. p. 157, and the suggestion is in the remarks upon the want of ovaria in certain monstrous births, and the male parts being found instead. The author (Sir E. Home) suggests that this may be explained by supposing the ovum, before impregnation, to have been equally adapted to becoming either a male or a female fœtus.

first race, by the daily loading of the back, would probably find a small grumous tumour to be formed in the flesh of that part. The next progeny would bring this tumour into the world with them. The life to which they were destined would increase it. The cause which first generated the tubercle being continued, it would go on, through every succession, to augment its size, till it attained the form and the bulk under which it now appears. This may serve for one instance: another, and that also of the passive sort, is taken from certain species of birds. Birds of the *crane* kind, as the crane itself, the heron, bittern, stork, have, in general, their thighs bare of feathers. This privation is accounted for from the habit of wading in water, and from the effect of that element to check the growth of feathers upon these parts; in consequence of which, the health and vegetation of the feathers declined through each generation of the animal; the tender down, exposed to cold and wetness, became weak, and thin, and rare, till the deterioration ended in the result which we see, of absolute nakedness. I will mention a third instance, because it is drawn from an active habit, as the two last were from passive habits; and that is the *pouch* of the pelican. The description which naturalists give of this organ is as follows: "From the lower edges of the under chap, hangs a bag, reaching from the whole length of the bill to the neck, which is said to be capable of containing fifteen quarts of water. This bag the bird has a power of wrinkling up into the hollow of the under chap. When the bag is empty, it is not seen: but when the bird has fished with success, it is incredible to what an extent it is often dilated. The first thing the pelican does in fishing is to fill the bag; and then it returns to digest its burden at leisure. The bird preys upon the large fishes, and hides them by dozens in its pouch. When the bill is opened to its widest extent, a person may run his head into the bird's mouth; and conceal it in this monstrous pouch, thus adapted for very singular purposes*." Now this extraordinary conformation is nothing more, say our philosophers, than the result of habit; not of the habit or effort of a single pelican, or of a single race of pelicans, but of a habit perpetuated through a long series of generations. The pelican soon found the conveniency of reserving in its mouth, when its appetite was glutted, the remainder of its prey, which is fish. The fulness produced by this attempt, of course stretched the skin which lies between the under chaps, as being the most yielding part of the mouth. Every distention increased

* Goldsmith, vol. vi. p. 52.

the cavity. The original bird, and many generations which succeeded him, might find difficulty enough in making the pouch answer this purpose; but future pelicans, entering upon life with a pouch derived from their progenitors, of considerable capacity, would more readily accelerate its advance to perfection, by frequently pressing down the sac with the weight of fish which it might now be made to contain.

These, or of this kind, are the analogies relied upon. Now, in the first place, the instances themselves are unauthenticated by testimony; and in theory, to say the least of them, open to great objections. Who ever read of camels without bunches, or with bunches less than those with which they are at present usually formed? A bunch, not unlike the camel's, is found between the shoulders of the buffalo; of the origin of which it is impossible to give the account here given. In the second example: Why should the application of water, which appears to promote and thicken the growth of feathers upon the bodies and breasts of geese, and swans, and other water-fowls, have divested of this covering the thighs of cranes? The third instance, which appears to me as plausible as any that can be produced, has this against it, that it is a singularity restricted to the species; whereas, if it had its commencement in the cause and manner which have been assigned, the like conformation might be expected to take place in other birds, which fed upon fish. How comes it to pass, that the pelican alone was the inventress, and her descendants the only inheritors, of this curious resource?[17]

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[17] The argument against the doctrine of *appetencies* may be urged thus upon well-known facts. If the camel's bunch has arisen from the animal, originally without any protuberance, having his back affected by burthens imposed, it would follow that human contrivance could alter the shape of beasts, which it most certainly cannot, as daily experience in regard to most domestic animals shows. No change of form produced immediately and directly, as by cutting, compressing, rubbing, can be perpetuated in the breed. All we can do with regard to animals, and all that any animals can do with regard to themselves, is indirectly, as by affecting their health, to affect the proportions of their parts, as bone, fat, muscle; the effects of which changes will be perceived in the progeny.

We have here been observing only upon the fact; but suppose the fact to be as the theory of appetencies assumes,—suppose the camel's bunch has been formed by weight and friction, and the pelican's pouch by the food distending the underchap,—in other words, suppose (contrary to what we have shown is the fact) that the changes induced in one animal or race at a given time, are pro-

But it is the less necessary to controvert the instances themselves, as it is a straining of analogy beyond all limits of reason and credibility,

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pagated and continue in their descendants,—it is plain that the sceptical argument gains nothing by this concession. For how are such changes continued? Only by the process of generation. Nay, how are they at first effected? By the operation of physical laws,—that is, by the constitution of matter. The quadruped's hunch and the bird's pouch, allowing the whole facts to be as the argument assumes it, are both originally formed and propagated afterwards by the means of the qualities with which matter is endowed; and the inference of design is not affected by the step thus added to the process of reasoning. It can manifestly make no difference to that inference, whether we hold that the bird's pouch is provided for its necessities by a conformation at all times belonging to it according to the constitution of the world, or by one superinduced according to that same constitution. The utmost that the sceptical hypothesis can gain by such concessions as we have been supposing to be made, is that the form of the world was at one time less perfect than it now is. A similar remark arises upon the conjecture of Laplace (in which others have followed him) respecting the original arrangement of the motions and longitudes of Jupiter's three first satellites, treated of in another note.—(*See notes to Chap.* xxii.)

to assert that birds, and beasts, and fish, with all their variety and complexity of organisation, have been brought into their forms, and distinguished into their several kinds and natures, by the same process (even if that process could be demonstrated, or had it ever been actually noticed) as might seem to serve for the gradual generation of a camel's bunch, or a pelican's pouch.

The solution, when applied to the works of nature *generally*, is contradicted by many of the phænomena, and totally inadequate to others. The *ligaments* or strictures, by which the tendons are tied down at the angles of the joints, could, by no possibility, be formed by the motion or exercise of the tendons themselves; by an appetency exciting these parts into action; or by any tendency arising therefrom. The tendency is all the other way: the *conatus* in constant opposition to them. Length of time does not help the case at all, but the reverse. The *valves* also in the blood-vessels could never be formed in the manner which our theorist proposes. The blood, in its right and natural course, has no tendency to form them. When obstructed or refluent, it has the contrary. These parts could not grow out of their use, though they had eternity to grow in.

The *senses* of animals appear to me altogether incapable of receiving the explanation of their origin which this theory affords. Including under the word "sense" the organ and the perception, we have no account of either. How will our philosopher get at *vision*, or make an eye? How should the blind animal affect sight, of which blind animals, we know, have neither conception nor desire? Affecting it, by what operation of its will, by what endeavour to see, could it so determine the fluids of its body, as to inchoate the formation of an eye? or suppose the eye formed, would the perception follow? The same of the other senses. And this objection holds its force, ascribe what you will to the hand of time, to the power of habit, to changes too slow to be observed by man, or brought within any comparison which he is able to make of past things with the present; concede what you please to these arbitrary and unattested suppositions, how will they help you? Here is no inception. No laws, no course, no powers of nature which prevail at present, nor any analogous to these, would give commencement to a new sense. And it is in vain to inquire how that might proceed, which could never *begin*.

I think the senses to be the most inconsistent with the hypothesis before us, of any part of the animal frame. But other parts are sufficiently so. The solution does not apply to the parts of animals, which have little in them of motion. If we could suppose joints and muscles to be gradually formed by action and exercise, what action or exercise could form a skull, and fill it with brains? No effort of the animal could determine the clothing of its skin. What *conatus* could give prickles to the porcupine or hedgehog, or to the sheep its fleece?

In the last place: What do these appetencies mean when applied to plants? I am not able to give a signification to the term, which can be transferred from animals to plants; or which is common to both. Yet a no less successful organisation is found in plants, than what obtains in animals. A solution is wanted for one, as well as the other.

Upon the whole, after all the schemes and struggles of a reluctant philosophy, the necessary resort is to a Deity. The marks of *design* are too strong to be gotten over. Design must have had a designer. That designer must have been a person. That person is God.

CHAPTER XXIV.

OF THE NATURAL ATTRIBUTES OF THE DEITY.

It is an immense conclusion, that there is a God; a perceiving, intelligent, designing Being; at the head of creation, and from whose will it proceeded. The *attributes* of such a Being, suppose his reality to be proved, must be adequate to the magnitude, extent, and multiplicity of his operations: which are not only vast beyond comparison with those performed by any other power; but, so far as respects our conceptions of them, infinite, because they are unlimited on all sides.

Yet the contemplation of a nature so exalted, however surely we arrive at the proof of its existence, overwhelms our faculties. The mind feels its powers sink under the subject. One consequence of which is, that from painful abstraction the thoughts seek relief in sensible images. Whence may be deduced the ancient, and almost universal propensity to idolatrous substitutions. They are the resources of a labouring imagination. False religions usually fall in with the natural propensity; true religions, or such as have derived themselves from the true, resist it.

It is one of the advantages of the revelations which we acknowledge, that, whilst they reject idolatry with its many pernicious accompaniments, they introduce the Deity to human apprehension, under an idea more personal, more determinate, more within its compass, than the theology of nature can do. And this they do by representing him exclusively under the relation in which he stands to ourselves; and, for the most part, under some precise character, resulting from that relation, or from the history of his providences: which method suits the span of our intellects much better than the universality which enters into the idea of God, as deduced from the views of nature. When, therefore, these representations are well founded in point of authority (for all depends upon that), they afford a condescension to the state of our faculties, of which they, who have most reflected on the subject, will be the first to acknowledge the want and the value.

Nevertheless, if we be careful to imitate the documents of our religion, by confining our explanations to what concerns ourselves, and do not affect more precision in our ideas than the subject allows of, the several terms which are employed to denote the attributes of the Deity may be made, even in natural religion, to bear a sense consistent with truth and reason, and not surpassing our comprehension.

These terms are,—Omnipotence, omniscience, omnipresence, eternity, self-existence, necessary existence, spirituality.

"Omnipotence," "omniscience," "infinite" power, "infinite" knowledge, are *superlatives;* expressing our conception of these attributes in the strongest and most elevated terms which language supplies. We ascribe power to the Deity under the name of "omnipotence," the strict and correct conclusion being, that a power which could create such a world as this is, must be, beyond all comparison, greater than any which we experience in ourselves, than any which we observe in other visible agents; greater also than any which we can want, for our individual protection and preservation, in the Being upon whom we depend. It is a power, likewise, to which we are not authorised, by our observation or knowledge, to assign any limits of space or duration.

Very much of the same sort of remark is applicable to the term "omniscience," infinite knowledge, or infinite wisdom. In strictness of language, there is a difference between knowledge and wisdom; wisdom always supposing action, and action directed by it. With respect to the first, viz. *knowledge,* the Creator must know, intimately, the constitution and properties of the things which he created: which seems also to imply a foreknowledge of their action upon one another, and of their changes; at least, so far as the same result from trains of physical and necessary causes. His omniscience also, as far as respects things present, is deducible from his nature, as an intelligent being, joined with the extent, or rather the universality, of his operations. Where he acts, he is: and where he is, he perceives. The *wisdom* of the Deity, as testified in the works of creation, surpasses all idea we have of wisdom, drawn from the highest intellectual operations of the highest class of intelligent beings with whom we are acquainted; and, which is of the chief importance to us, whatever be its compass or extent, which it is evidently impossible that we should be able to determine, it must be adequate to the conduct of that order of things under which we live. And this is enough. It is of very inferior consequence, by what terms we express our notion, or rather our admiration, of this attribute. The terms, which the piety and the usage of language have rendered habitual to us, may be as proper as any other. We can trace this attribute much beyond what is necessary for any conclusion to which we have occasion to apply it. The degree of knowledge and power requisite for the formation of created nature cannot, with respect to us, be distinguished from infinite.[18]

The divine "omnipresence" stands, in natural theology, upon this foundation:—In every part and place of the universe with which we are acquainted, we perceive the exertion of a power, which we believe, mediately or immediately, to proceed from the Deity. For instance: in what part or point of space, that has ever been explored, do we not discover attraction? In what regions do we not find light? In what accessible portion of our globe do we not meet with gravity, magnetism, electricity: together with the properties also and powers of organised substances, of vegetable or of animated nature? Nay, further, we may ask, What kingdom is there of nature, what corner of space, in which there is any thing

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[18] It is not perhaps quite correct to state that "*infinite*," as applied to the Deity, means only a degree of power or wisdom beyond all comparison greater than any such qualities possessed by ourselves; and that this term, as well as "*omnipotence*," is merely a superlative. Those words also designate the existence of the attributes in such a degree, that any extent whatever of them being either presented to our observation, or conceived by our imagination, the Deity possesses them in a still greater degree—a degree to which our conception can affix no bounds.

that can be examined by us, where we do not fall upon contrivance and design? The only reflection perhaps which arises in our minds from this view of the world around us is, that the laws of nature everywhere prevail; that they are uniform and universal. But what do you mean by the laws of nature, or by any law? Effects are produced by power, not by laws. A law cannot execute itself. A law refers us to an agent. Now an agency so general, as that we cannot discover its absence, or assign the place in which some effect of its continued energy is not found, may, in popular language at least, and, perhaps, without much deviation from philosophical strictness, be called universal: and, with not quite the same, but with no inconsiderable propriety, the person, or Being, in whom that power resides, or from whom it is derived, may be taken to be *omnipresent*. He who upholds all things by his power, may be said to be every where present.

This is called a virtual presence. There is also what metaphysicians denominate an essential ubiquity; and which idea the language of Scripture seems to favour: but the former, I think, goes as far as natural theology carries us.[19]

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[19] Upon this confessedly abstruse subject some statements will be found in the Appendix. The three doc-

"Eternity" is a negative idea, clothed with a positive name. It supposes, in that to which it is applied, a present existence; and is the negation of a beginning or an end of that existence. As

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trines are—ubiquity by *diffusion*, *virtual* ubiquity, or that of power only, and ubiquity of *essence*. The last is expressed thus, to the exclusion of the second, by Sir I. Newton, in the Schol. Gen. to the Principia :—"Omnipræsens est non per *virtutem* solam sed etiam per *substantiam ;* nam virtus sine substantiâ subsistere non potest." It is perhaps hardly correct to say that Natural Theology carries us not to the idea of Essential Ubiquity. Dr. Clarke makes Essential Ubiquity one part of his conclusion from the argument *à priori ;* and though his adversaries (see Chev. Ramsay, book i. prop. 8. Schol.) charged him with adopting the Diffusive Ubiquity, he is plainly not subject to this observation. The followers of Socinus, who maintained Virtual Ubiquity, are ably combated, and the Essential Ubiquity defended by Dr. Hancock (Boyle Lecture, vol. ii. p. 222), upon arguments drawn from natural religion. We are here, it is to be observed, only speaking of the idea or doctrine itself having been attained independent of Revelation; and not inquiring how far those arguments of unassisted reason have enforced the belief of it, or even made it comprehensible. Descartes (Principia I. xxii.) does not enumerate Ubiquity at all among the attributes, unless in so far as it may be included under infinite perfection generally ascribed.—(I. xxii. xxvii., II. xxxvi., III. i.)

applied to the Deity, it has not been controverted by those who acknowledge a Deity at all. Most assuredly, there never was a time in which nothing existed, because that condition must have continued. The universal *blank* must have remained; nothing could rise up out of it; nothing could ever have existed since; nothing could exist now. In strictness, however, we have no concern with duration prior to that of the visible world. Upon this article therefore of theology, it is sufficient to know that the contriver necessarily existed before the contrivance.

"Self-existence" is another negative idea, viz. the negation of a preceding cause, as of a progenitor, a maker, an author, a creator.[20]

"Necessary existence" means demonstrable existence.[21]

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[20] *Self-existent* means, in any intelligible sense, only uncreated, independent, eternal. The ancient doctrine of *Self-created*, if it goes beyond the mere negative sense, is absolutely unintelligible, or, to use Dr. Clarke's words, "an express contradiction."

[21] *Necessary*, properly means demonstrable in such a way, that the contrary involves a contradiction and is inconceivable. Dr. Paley here uses the word demonstrable *per se* in this sense; for which he has the authority of several metaphysical writers.

"Spirituality" expresses an idea, made up of a negative part, and of a positive part. The negative part consists in the exclusion of some of the known properties of matter, especially of solidity, of the *vis inertiæ*, and of gravitation. The positive part comprises perception, thought, will, power, *action*, by which last term is meant the origination of motion; the quality, perhaps, in which resides the essential superiority of spirit over matter, "which cannot move, unless it be moved; and cannot but move, when impelled by another."* I apprehend that there can be no difficulty in applying to the Deity both parts of this idea.

* Bishop Wilkins's Principles of Natural Religion, p. 106.

CHAPTER XXV.

OF THE UNITY OF THE DEITY.

Of the "Unity of the Deity," the proof is, the *uniformity* of plan observable in the universe. The universe itself is a system; each part either depending upon other parts, or being connected with other parts by some common law of motion, or by the presence of some common substance. One principle of gravitation causes a stone to drop towards the earth, and the moon to wheel round it. One law of attraction carries all the different planets about the sun.[22] This philo-

[22] Bishop Brinkley considers the subject of nebulæ and double stars "as hardly yet sufficiently investigated" for affording grounds of additional illustration to the cultivator of Natural Theology; and it is much to be regretted that he, on this account, abandoned the design, which he says he had at one time formed, of adding some notes upon this branch of astronomical science. The Appendix will contain a reference to this subject, particularly to the additional argument drawn from the revolution of double stars in favour of the universal extension of gravitation.

The fact of the heavenly bodies which form our sophers demonstrate. There are also other points of agreement amongst them, which may be con-

system all moving in the same direction of revolution, is deserving of the deepest attention when we consider that it leads to the most important result of the stability of the system explained above (chap. xxii., notes); and that it is one of innumerable arrangements which might have been made, and none of which could have led to this result. In any other case equal roots, or imaginary roots, or both, must have found their way into the equation from which the law of stability is deduced. (*Méc. Cél.* l. ii. c. 7, s. 55, 57, and liv. xv. c. 1.) Now the same profound geometrician has shown, in another work, by the calculus of probabilities, that it is above four millions of millions to one in favour of the forty-three motions from west to east (including rotation as well as revolution and the motions of the sun and of the rings, as well as of the planets and satellites) having been directed by one original or First Cause; and by the same calculus he has shown the probability of the sun's rising again on the morrow of any given day, to be not much more than 1,800,000 to one, or, in other words, that this event is above two million times less probable than the truth of the position that the motions in our system were designed by one First Cause. This illustrious philosopher has been censured for not drawing in terms the conclusion to which his sublime researches, with those of Lagrange, have led the way, and at which he must himself have arrived,—that a Supreme Intelligence alone sidered as marks of the identity of their origin, and of their intelligent Author. In all are found the conveniency and stability derived from gravitation. They all experience vicissitudes of days and nights, and changes of season. They all, at least Jupiter, Mars, and Venus, have the same advantages from their atmosphere as we have. In all the planets, the axes of rotation are permanent. Nothing is more probable than that the same attracting influence, acting according to the same rule, reaches to the fixed stars: but, if this be only probable, another thing is certain, *viz.* that the same element of light does. The light from a fixed star affects our eyes in the same manner, is refracted and reflected according to the same laws, as the light of a candle. The velocity of the light of the fixed stars is also the same as the velocity of the light of the sun, reflected from the satellites of Jupiter. The heat

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could have formed this magnificent and stable system. His reason for abstaining from indulging in such contemplations probably was that his work is purely mathematical, and that this would have been a digression into another science. But the reason is not sufficient, and the omission must ever be lamented as a defect in a work so nearly perfect. Mr. Whewell has made some ingenious strictures upon this subject in his able and learned *Bridgewater Treatise*, b. iii. c. 5 and 6.

of the sun, in kind, differs nothing from the heat of a coal fire.[23]

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[23] The law by which the distances of the planets are regulated was referred to in a note by Bishop Brinkley to the 22nd chapter, and affords an evidence of unity of design not to be passed over. It is this nearly, but not exactly. Form a series of numbers, each consisting of the number 4 added to the number 3, but to the number 3 multiplied successively by 0, 1, 2, 4, 8, 16, and the other powers of 2: the mean distance of Mercury being 4, this series will represent the mean distances of the other planets successively. Taking the four newly-discovered planets between Mars and Jupiter as one—the distances of Venus, the Earth, and Jupiter, coincide with the series exactly; the others slightly differ. Thus

Mercury by the supposition	4		4
Venus by the theory . .	7	by observation	7
Earth	10	. .	10
Mars	16	. .	15
New planets . .	28	. .	27
Vesta . .		23·73	
Juno . .		26·67	
Ceres . .		27·67	
Pallas . .		27·68	
Jupiter	52	. . .	52
Saturn	100	. .	95
Uranus	196	. . .	192

"We cannot but remark," says Bishop Brinkley, "the near agreement of the law with the exact mean

In our own globe, the case is clearer. New countries are continually discovered, but the old laws of nature are always found in them: new plants, perhaps, or animals, but always in company with plants and animals which we already know; and always possessing many of the same general properties. We never get amongst such original, or totally different, modes of existence, as to indicate, that we are come into the province of a different Creator, or under the direction of a different will. In truth, the same order of things attends us, wherever we go. The elements act upon one another, electricity operates, the tides rise and fall, the magnetic needle elects its position, in one region of the earth and sea, as well as in another. One atmosphere invests all parts

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distances, and cannot hesitate to pronounce that those were assigned according to a law, although we are entirely ignorant of the exact law and of the reason for that law."

This sentence derives a peculiar, though a painful interest from the circumstance of its being in all likelihood the last written by this profound and accomplished astronomer, on subjects connected with his favourite study. It closed the communication received from him, which was dated at Cloyne, June 25, 1835; and he died at Dublin, in less than three months after (September 14).

of the globe, and connects all; one sun illuminates, one moon exerts its specific attraction upon all parts. If there be a variety in natural effects, as, *e. g.* in the tides of different seas, that very variety is the result of the same cause, acting under different circumstances. In many cases this is proved; in all, is probable.

The inspection and comparison of *living* forms add to this argument examples without number. Of all large terrestrial animals the structure is very much alike; their senses nearly the same; their natural functions and passions nearly the same; their viscera nearly the same, both in substance, shape, and office: digestion, nutrition, circulation, secretion, go on, in a similar manner, in all; the great circulating fluid is the same; for, I think, no difference has been discovered in the properties of *blood,* from whatever animal it be drawn. The experiment of transfusion proves that the blood of one animal will serve for another. The *skeletons* also of the larger terrestrial animals show particular varieties, but still under a great general affinity. The resemblance is somewhat less, yet sufficiently evident, between quadrupeds and birds. They are all alike in five respects, for one in which they differ.

In *fish,* which belong to another department, as it were, of nature, the points of comparison become fewer. But we never lose sight of our analogy, *e. g.* we still meet with a stomach, a liver, a spine; with bile and blood; with teeth; with eyes (which eyes are only slightly varied from our own, and which variation, in truth, demonstrates, not an interruption, but a continuance of the same exquisite plan; for it is the adaptation of the organ to the element, *viz.* to the different refraction of light passing into the eye out of a denser medium). The provinces, also, themselves of water and earth, are connected by the species of animals which inhabit both; and also by a large tribe of aquatic animals, which closely resemble the terrestrial in their internal structure; I mean the cetaceous tribe, which have hot blood, respiring lungs, bowels, and other essential parts, like those of land-animals. This similitude, surely, bespeaks the same creation and the same Creator.

Insects and *shell-fish* appear to me to differ from other classes of animals the most widely of any. Yet even here, besides many points of particular resemblance, there exists a general relation of a peculiar kind. It is the relation of inversion; the law of contariety: namely, that, whereas, in other animals, the bones, to which the muscles are attached, lie *within* the body, in insects and shell-fish they lie on the *outside* of it. The shell of a lobster performs to the animal the office of a *bone*, by furnishing to the tendons that fixed basis or immovable fulcrum, without which, mechanically, they could not act. The crust of an insect is its shell, and answers the like purpose. The shell also of an oyster stands in the place of a *bone;* the bases of the muscles being fixed to it, in the same manner as, in other animals, they are fixed to the bones. All which (under wonderful varieties, indeed, and adaptations of form) confesses an imitation, a remembrance, a carrying on, of the same plan.

The observations here made are equally applicable to plants; but, I think, unnecessary to be pursued. It is a very striking circumstance, and also sufficient to prove all which we contend for, that, in this part likewise of organised nature, we perceive a continuation of the *sexual* system.

Certain however it is, that the whole argument for the divine unity goes no farther than to an unity of counsel.[24]

It may likewise be acknowledged, that no argu-

[24] The extraordinary discoveries in geology made since Dr. Paley's time by the study of fossil osteology by no means impair his argument as to Unity when rightly considered. These will be fully discussed in the Appendix, and they throw material light upon other branches of the subject.

ments which we are in possession of, exclude the ministry of subordinate agents. If such there be, they act under a presiding, a controlling will; because they act according to certain general restrictions, by certain common rules, and, as it should seem, upon a general plan: but still such agents, and different ranks, and classes and degrees of them, may be employed.[25]

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[25] Addison, a person of practical understanding, calm temperament, and widely removed from all enthusiasm, (Spectator, No. 110,) states very plainly his belief in spirits, not in the religious and philosophical sense of subordinate agents, adopted by Dr. Paley, but in the popular sense of ghosts. He rests his opinion, as Dr. Johnson did his strong inclination towards the same belief, upon the cogency of testimony. Respecting witchcraft, he elsewhere (No. 117) expresses the inclination of his opinion in favour of it generally and abstractedly; but refusing all credit to particular instances. The feeling which dictates such a disposition to believe in a spiritual world is natural, as well as amiable. But it may be questioned if religion does not lose as much as it can gain by indulging in it.

CHAPTER XXVI.

OF THE GOODNESS OF THE DEITY.

THE proof of the *divine goodness* rests upon two propositions: each, as we contend, capable of being made out by observations drawn from the appearances of nature.

The first is, "that in a vast plurality of instances in which contrivance is perceived, the design of the contrivance is *beneficial*."

The second, "that the Deity has superadded *pleasure* to animal sensations, beyond what was necessary for any other purpose, or when the purpose, so far as it was necessary, might have been effected by the operation of pain."

First, "in a vast plurality of instances in which contrivance is perceived, the design of the contrivance is *beneficial*."

No productions of nature display contrivance so manifestly as the parts of animals; and the parts of animals have all of them, I believe, a real, and, with very few exceptions, all of them a known and intelligible subserviency to the use of the animal. Now, when the multitude of animals is considered, the number of parts in each, their figure and fitness, the faculties depending upon them, the variety of species, the complexity of structure, the success, in so many cases, and felicity of the result, we can never reflect, without the profoundest adoration, upon the character of that Being from whom all these things have proceeded: we cannot help acknowledging what an exertion of benevolence creation was; of a benevolence how minute in its care, how vast in its comprehension!

When we appeal to the parts and faculties of animals, and to the limbs and senses of animals in particular, we state, I conceive, the proper medium of proof for the conclusion which we wish to establish. I will not say, that the insensible parts of nature are made solely for the sensitive parts: but this I say, that, when we consider the benevolence of the Deity, we can only consider it in relation to sensitive being. Without this reference, or referred to any thing else, the attribute has no object; the term has no meaning. Dead matter is nothing. The parts, therefore, especially the limbs and senses, of animals, although they constitute, in mass and quantity, a small portion of the material creation, yet, since they alone are instruments of perception, they compose what may be called the whole of visible nature, estimated with a view to the disposition of its Author. Consequently, it is in *these* that we are to seek his character. It is by these that we are to prove that the world was made with a benevolent design.

Nor is the design abortive. It is a happy world after all. The air, the earth, the water, teem with delighted existence. In a spring noon, or a summer evening, on whichever side I turn my eyes, myriads of happy beings crowd upon my view. "The insect youth are on the wing." Swarms of new-born *flies* are trying their pinions in the air. Their sportive motions, their wanton mazes, their gratuitous activity, their continual change of place without use or purpose, testify their joy, and the exultation which they feel in their lately discovered faculties. A *bee* amongst the flowers in spring is one of the most cheerful objects that can be looked upon. Its life appears to be all enjoyment; so busy, and so pleased; yet it is only a specimen of insect life, with which by reason of the animal being half domesticated, we happen to be better acquainted than we are with that of others. The *whole-winged* insect tribe, it is probable, are equally intent upon their proper employments, and, under every variety of constitution, gratified, and perhaps equally gratified, by the offices which the

Author of their nature has assigned to them. But the atmosphere is not the only scene of enjoyment for the insect race. Plants are covered with aphides, greedily sucking their juices, and constantly, as it should seem, in the act of sucking. It cannot be doubted but that this is a state of gratification. What else should fix them so close to the operation, and so long? Other species are *running about*, with an alacrity in their motions which carries with it every mark of pleasure. Large patches of ground are sometimes half covered with these brisk and sprightly natures. If we look to what the *waters* produce, shoals of the fry of fish frequent the margins of rivers, of lakes, and of the sea itself. These are so happy, that they know not what to do with themselves. Their attitudes, their vivacity, their leaps out of the water, their frolics in it (which I have noticed a thousand times with equal attention and amusement), all conduce to show their excess of spirits, and are simply the effects of that excess. Walking by the sea-side, in a calm evening, upon a sandy shore, and with an ebbing tide, I have frequently remarked the appearance of a dark cloud, or, rather, very thick mist, hanging over the edge of the water, to the height, perhaps, of half a yard, and of the breadth of two or three yards, stretching along the coast as far as the eye could reach, and always retiring with the water. When this cloud came to be examined it proved to be nothing else than so much space filled with young *shrimps*, in the act of bounding into the air from the shallow margin of the water, or from the wet sand. If any motion of a mute animal could express delight, it was this: if they had meant to make signs of their happiness, they could not have done it more intelligibly. Suppose, then, what I have no doubt of, each individual of this number to be in a state of positive enjoyment; what a sum, collectively, of gratification and pleasure have we here before our view![26]

The *young* of all animals appear to me to receive pleasure simply from the exercise of their limbs and bodily faculties, without reference to any end to be attained, or any use to be answered by the exertion. A child, without knowing any thing of the use of language, is in a high degree delighted with being able to speak. Its incessant repetition of a few articulate sounds, or, perhaps,

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[26] To these considerations it must be added, that the lives of such animals may be only apparently short. If time is but the succession of ideas, then, as Soame Jenyns has observed, the insect that flutters for a single summer's day may in reality live as long as the tortoise that breathes for a century.

of the single word which it has learnt to pronounce, proves this point clearly. Nor is it less pleased with its first successful endeavours to walk, or rather to run (which precedes walking), although entirely ignorant of the importance of the attainment to its future life, and even without applying it to any present purpose. A child is delighted with speaking, without having any thing to say, and with walking, without knowing where to go. And, prior to both these, I am disposed to believe, that the waking hours of infancy are agreeably taken up with the exercise of vision, or perhaps, more properly speaking, with learning to see.

But it is not for youth alone that the great Parent of creation hath provided. Happiness is found with the purring cat, no less than with the playful kitten; in the arm-chair of dozing age, as well as in either the sprightliness of the dance, or the animation of the chase. To novelty, to acuteness of sensation, to hope, to ardour of pursuit, succeeds, what is, in no inconsiderable degree, an equivalent for them all, "perception of ease." Herein is the exact difference between the young and the old. The young are not happy but when enjoying pleasure; the old are happy when free from pain. And this constitution suits with the degrees of animal power which they respectively possess. The vigour of youth was to be stimulated to action by impatience of rest; whilst to the imbecility of age, quietness and repose become positive gratifications. In one important respect the advantage is with the old. A state of ease is, generally speaking, more attainable than a state of pleasure. A constitution, therefore, which can enjoy ease, is preferable to that which can taste only pleasure. This same perception of ease oftentimes renders old age a condition of great comfort; especially when riding at its anchor after a busy or tempestuous life. It is well described by Rousseau, to be the interval of repose and enjoyment between the hurry and the end of life. How far the same cause extends to other animal natures cannot be judged of with certainty. The appearance of satisfaction with which most animals, as their activity subsides, seek and enjoy rest, affords reason to believe, that this source of gratification is appointed to advanced life, under all, or most, of its various forms. In the species with which we are best acquainted, namely our own, I am far, even as an observer of human life, from thinking that youth is its happiest season, much less the only happy one: as a Christian, I am willing to believe that there is a great deal of truth in the following representation given by a very pious writer, as well as excellent man*: "To the intelligent and virtuous, old age presents a scene of tranquil enjoyments, of obedient appetite, of well-regulated affections, of maturity in knowledge, and of calm preparation for immortality. In this serene and dignified state, placed as it were on the confines of two worlds, the mind of a good man reviews what is past with the complacency of an approving conscience; and looks forward, with humble confidence in the mercy of God, and with devout aspirations towards his eternal and ever-increasing favour."

What is seen in different stages of the same life, is still more exemplified in the lives of different animals. Animal enjoyments are infinitely *diversified*. The modes of life, to which the organisation of different animals respectively determines them, are not only of various but of opposite kinds. Yet each is happy in its own. For instance: animals of prey live much alone; animals of a milder constitution in society. Yet the herring, which lives in shoals, and the sheep, which lives in flocks, are not more happy in a crowd, or more contented amongst their companions, than is the pike, or the lion, with the deep solitudes of the pool, or the forest.

* Father's Instructions; by Dr. Percival, of Manchester, p. 317.

But it will be said, that the instances which we have here brought forward, whether of vivacity or repose, or of apparent enjoyment derived from either, are picked and favourable instances. We answer, first, that they are instances, nevertheless, which comprise large provinces of sensitive existence; that every case which we have described is the case of millions. At this moment, in every given moment of time, how many myriads of animals are eating their food, gratifying their appetites, ruminating in their holes, accomplishing their wishes, pursuing their pleasures, taking their pastimes! In each individual, how many things must go right for it to be at ease; yet how large a proportion out of every species is so in every assignable instant! Secondly, we contend, in the terms of our original proposition, that throughout the whole of life, as it is diffused in nature, and as far as we are acquainted with it, looking to the average of sensations, the plurality and the preponderancy is in favour of happiness by a vast excess. In our own species, in which perhaps the assertion may be more questionable than any other, the prepollency of good over evil, of health, for example, and ease, over pain and distress, is evinced by the very notice which calamities excite. What inquiries does the sickness of our friends produce! what conversation their misfortunes! This shows that the common course of things is in favour of happiness; that happiness is the rule, misery the exception. Were the order reversed, our attention would be called to examples of health and competency, instead of disease and want.

One great cause of our insensibility to the goodness of the Creator, is the very *extensiveness* of his bounty. We prize but little what we share only in common with the rest, or with the generality of our species. When we hear of blessings, we think forthwith of successes, of prosperous fortunes, of honours, riches, preferments, *i. e.* of those advantages and superiorities over others, which we happen either to possess, or to be in pursuit of, or to covet. The common benefits of our nature entirely escape us. Yet these are the great things. These constitute what most properly ought to be accounted blessings of Providence; what alone, if we might so speak, are worthy of its care. Nightly rest and daily bread, the ordinary use of our limbs, and senses, and understandings, are gifts which admit of no comparison with any other. Yet because almost every man we meet with possesses these, we leave them out of our enumeration. They raise no sentiment; they move no gratitude. Now, herein is our judgment perverted by our selfishness. A blessing ought in truth to be the *more* satisfactory, the bounty at least of the donor is rendered more conspicuous, by its very diffusion, its commonness, its cheapness: by its falling to the lot, and forming the happiness, of the great bulk and body of our species, as well as of ourselves. Nay, even when we do not possess it, it ought to be matter of thankfulness that others do. But we have a different way of thinking. We court distinction. That is not the worst: we *see* nothing but what has distinction to recommend it. This necessarily contracts our views of the Creator's beneficence within a narrow compass; and most unjustly. It is in those things which are so common as to be no distinction, that the amplitude of the Divine benignity is perceived.

But pain, no doubt, and privations exist, in numerous instances, and to a great degree, which collectively would be very great, if they were compared with any other thing than with the mass of animal fruition. For the application, therefore, of our proposition to that *mixed* state of things which these exceptions induce, two rules are necessary, and both, I think, just and fair rules. One is, that we regard those effects alone which are accompanied with proofs of intention: The other, that when we cannot resolve all appearances into benevolence of design, we make the few give place to the many; the little to the great; that we take our judgment from a large and decided preponderancy, if there be one.[27]

I crave leave to transcribe into this place what

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[27] This passage, with others which afterwards occur in this work, as well as the part here quoted from the author's Moral Philosophy, has been, it should seem, somewhat misunderstood by several excellent authors, who have treated him as if he were denying the existence of evil; and have referred, though without any sceptical view, to the old dilemma of the Epicureans, stated by Lactantius:—"Aut vult, et non potest; aut potest et non vult tollere mala." But Dr. Paley's whole discourse upon this subject must be taken as an attempt, and a successful one, to diminish the apparent amount of evil, by showing that many of the things accounted evils are less bad than they seem to be. He explains the deductions which are fairly to be made; he shows the compensations which exist; he proves that out of evil good frequently arises. Having done this, evil still remains, but in an amount exceedingly reduced; and this remaining portion is that concerning which alone the question arises. All that follows of the text must be read with this view; and it must be admitted that nothing can be more legitimate than the scope of the reasoning employed if regarded in this light. Viewed in any other, it would be liable to the objections which have been urged against it.

I have said upon this subject in my Moral Philosophy:—

"When God created the human species, either he wished their happiness, or he wished their misery, or he was indifferent and unconcerned about either.

"If he had wished our misery, he might have made sure of his purpose, by forming our senses to be so many sores and pains to us, as they are now instruments of gratification and enjoyment: or by placing us amidst objects so ill suited to our perceptions, as to have continually offended us, instead of ministering to our refreshment and delight. He might have made, for example, every thing we tasted, bitter; every thing we saw, loathsome; every thing we touched, a sting; every smell, a stench; and every sound, a discord.

"If he had been indifferent about our happiness or misery, we must impute to our good fortune (as all design by this supposition is excluded) both the capacity of our senses to receive pleasure, and the supply of external objects fitted to produce it.

"But either of these, and still more both of them, being too much to be attributed to accident, nothing remains but the first supposition, that God, when he created the human species, wished their happiness; and made for them the provision which he has made, with that view and for that purpose.

"The same argument may be proposed in different terms; *thus:* Contrivance proves design; and the predominant tendency of the contrivance indicates the disposition of the designer. The world abounds with contrivances; and all the contrivances which we are acquainted with are directed to beneficial purposes. Evil, no doubt, exists; but is never, that we can perceive, the *object* of contrivance. Teeth are contrived to eat, not to ache; their aching now and then is incidental to the contrivance, perhaps inseparable from it: or even, if you will, let it be called a defect in the contrivance; but it is not the object of it. This is a distinction which well deserves to be attended to. In describing implements of husbandry, you would hardly say of the sickle, that it is made to cut the reaper's hand: though from the construction of the instrument, and the manner of using it, this mischief often follows. But if you had occasion to describe instruments of torture, or execution,—this engine, you would say, is to extend the sinews; this to dislocate the joints; this to break the bones; this to scorch the soles of the feet. Here, pain and misery are the very objects of the contrivance. Now, nothing of this sort is to be found in the works of nature.

We never discover a train of contrivance to bring about an evil purpose. No anatomist ever discovered a system of organisation calculated to produce pain and disease; or, in explaining the parts of the human body, ever said, this is to irritate; this to inflame; this duct is to convey the gravel to the kidneys; this gland to secrete the humour which forms the gout: if by chance he come at a part of which he knows not the use, the most he can say is, that it is useless; no one ever suspects that it is put there to incommode, to annoy, or to torment."

The TWO CASES which appear to me to have the most difficulty in them, as forming the most of the appearance of exception to the representation here given, are those of *venomous* animals, and of animals *preying* upon one another. These properties of animals, wherever they are found, must, I think, be referred to design; because there is in all cases of the first, and in most cases of the second, an express and distinct organisation provided for the producing of them. Under the first head, the fangs of vipers, the stings of wasps and scorpions, are as clearly intended for their purpose, as any animal structure is for any purpose the most incontestably beneficial. And the same thing must, under the second head, be acknowledged of the talons and beaks of birds, of the tusks, teeth and claws of beasts of prey; of the shark's mouth, of the spider's web, and of numberless weapons of offence belonging to different tribes of voracious insects. We cannot, therefore, avoid the difficulty by saying, that the effect was not intended. The only question open to us is, whether it be ultimately evil. From the confessed and felt imperfection of our knowledge, we ought to presume, that there may be consequences of this œconomy which are hidden from us: from the benevolence which pervades the general designs of nature, we ought also to presume, that these consequences, if they could enter into our calculation, would turn the balance on the favourable side. Both these I contend to be reasonable presumptions. Not reasonable presumptions, if these two cases were the only cases which nature presented to our observation; but reasonable presumptions under the reflection, that the cases in question are combined with a multitude of intentions, all proceeding from the same author, and all, except these, directed to ends of undisputed utility. Of the vindications, however, of this œconomy, which we are able to assign, such as most extenuate the difficulty are the following.

With respect to *venomous* bites and stings, it may be observed,—

1. That, the animal itself being regarded, the

faculty complained of is *good;* being conducive, in all cases, to the defence of the animal; in some cases, to the subduing of its prey; and in some, probably, to the killing of it, when caught, by a mortal wound, inflicted in the passage to the stomach, which may be no less merciful to the victim, than salutary to the devourer. In the viper, for instance, the poisonous fang may do that which, in other animals of prey, is done by the crush of the teeth. Frogs and mice might be swallowed alive without it.

2. But it will be said, that this provision, when it comes to the case of bites, deadly even to human bodies, and to those of large quadrupeds, is greatly *overdone;* that it might have fulfilled its use, and yet have been much less deleterious than it is. Now I believe the case of bites which produce death in large animals (of stings I think there are none) to be very few. The experiments of the Abbé Fontana, which were numerous, go strongly to the proof of this point. He found that it required the action of five exasperated vipers to kill a dog of a moderate size; but that to the killing of a mouse, or a frog, a single bite was sufficient; which agrees with the use which we assign to the faculty. The Abbé seemed to be of opinion, that the bite even of the rattlesnake would not usually be mortal; allowing,

however, that in certain particularly unfortunate cases, as when the puncture had touched some very tender part, pricked a principal nerve, for instance, or, as it is said, some more considerable lymphatic vessel, death might speedily ensue.

3. It has been, I think, very justly remarked, concerning serpents, that, whilst only a few species possess the venomous property, that property guards the whole tribe. The most innocuous snake is avoided with as much care as a viper. Now the terror with which large animals regard this class of reptiles is its protection; and this terror is founded on the formidable revenge, which a few of the number, compared with the whole, are capable of taking. The species of serpents, described by Linnæus, amount to two hundred and eighteen, of which thirty-two only are poisonous.

4. It seems to me, that animal constitutions are provided, not only for each element, but for each state of the elements, *i. e.* for every climate, and for every temperature; and that part of the mischief complained of arises from animals (the human animal most especially) occupying situations upon the earth which do not belong to them, nor were ever intended for their habitation. The folly and wickedness of mankind, and necessities proceeding from these causes, have driven multi-

tudes of the species to seek a refuge amongst burning sands, whilst countries, blessed with hospitable skies, and with the most fertile soils, remain almost without a human tenant. We invade the territories of wild beasts and venomous reptiles, and then complain that we are infested by their bites and stings. Some accounts of Africa place this observation in a strong point of view. "The deserts," says Adanson, "are entirely barren, except where they are found to produce serpents; and in such quantities, that some extensive plains are almost entirely covered with them." These are the natures appropriated to the situation. Let them enjoy their existence; let them have their country. Surface enough will be left to man, though his numbers were increased a hundred-fold, and left to him, where he might live exempt from these annoyances.

The SECOND CASE, *viz.* that of animals *devouring* one another, furnishes a consideration of much larger extent. To judge whether, as a general provision, this can be deemed an *evil*, even so far as we understand its consequences, which, probably, is a partial understanding, the following reflections are fit to be attended to.[28]

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[28] The subject of apparently conflicting contrivances, including conflicting instincts, as well as apparently

1. Immortality upon this earth is out of the question. Without death there could be no generation, no sexes, no parental relation, *i. e.* as things are constituted, no animal happiness. The particular duration of life, assigned to different animals, can form no part of the objection; because, whatever that duration be, whilst it remains finite

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imperfect contrivances and instincts, will be considered at large in the Appendix. The progress of science is constantly diminishing the number of such instances, as far as our ignorance of design goes. That some conflict will continue; in other words, that evil to a certain amount will, after all deductions, be found to exist, cannot be doubted. But that an immense preponderance of good exists in every department of nature, both of matter and of mind, is so clear, that, arguing as we do on every other subject, we have a right to impute the perception of any evil at all to our own ignorance; and to conclude that, if we knew the whole system, and could extend our comprehension to the entire plan of creation, we should no longer believe there was evil at all. Of the different hypotheses to which we may have recourse for explaining what we are unable legitimately to solve, the Probationary State is one, and is the one which appears to tally best with the facts. It is hardly necessary to add that we are now, as throughout these notes, after the example of the author, confining ourselves altogether to the intimations received from natural reason and observation, unaided by the light of revelation.

and limited, it may always be asked, why it is no longer. The natural age of different animals varies, from a single day to a century of years. No account can be given of this; nor could any be given, whatever other proportion of life had obtained amongst them.

The term then of life in different animals being the same as it is, the question is what mode of taking it away is the best even for the animal itself.

Now, according to the established order of nature (which we must suppose to prevail, or we cannot reason at all upon the subject), the three methods by which life is usually put an end to are acute diseases, decay, and violence. The simple and natural life of *brutes* is not often visited by acute distempers; nor could it be deemed an improvement of their lot if they were. Let it be considered, therefore, in what a condition of suffering and misery a brute animal is placed which is left to perish by *decay*. In human sickness or infirmity, there is the assistance of man's rational fellow-creatures, if not to alleviate his pains, at least to minister to his necessities, and to supply the place of his own activity. A brute, in his wild and natural state, does every thing for himself. When his strength, therefore, or his speed, or his limbs, or his senses fail him, he is delivered over, either to absolute famine or to the protracted wretchedness of a life slowly wasted by the scarcity of food. Is it then to see the world filled with drooping, superannuated, half-starved, helpless, and unhelped animals that you would alter the present system of pursuit and prey?

2. Which system is also to them the spring of motion and activity on both sides. The pursuit of its prey forms the employment, andappears to constitute the pleasure, of a considerable part of the animal creation. The using of the means of defence, or flight, or precaution, forms also the business of another part. And even of this latter tribe, we have no reason to suppose, that their happiness is much molested by their fears. Their danger exists continually; and in some cases they seem to be so far sensible of it, as to provide, in the best manner they can, against it; but it is only when the attack is actually made upon them, that they appear to suffer from it. To contemplate the insecurity of their condition with anxiety and dread, requires a degree of reflection, which (happily for themselves) they do not possess. A *hare,* notwithstanding the number of its dangers and its enemies, is as playful an animal as any other.

3. But, to do justice to the question, the system of animal *destruction* ought always to be

considered in strict connexion with another property of animal nature, viz. *superfecundity*. They are countervailing qualities. One subsists by the correction of the other. In treating, therefore, of the subject under this view, (which is, I believe, the true one,) our business will be, first, to point out the advantages which are gained by the powers in nature of a superabundant multiplication; and then to show, that these advantages are so many reasons for appointing that system of national hostilities, which we are endeavouring to account for.

In almost all cases, nature produces her supplies with profusion. A single cod-fish spawns, in one season, a greater number of eggs than all the inhabitants of England amount to. A thousand other instances of prolific generation might be stated, which, though not equal to this, would carry on the increase of the species with a rapidity which outruns calculation, and to an immeasurable extent. The advantages of such a constitution are two: first, that it tends to keep the world always full; whilst, secondly, it allows the proportion between the several species of animals to be differently modified, as different purposes require, or as different situations may afford for them room and food. Where this vast fecundity meets with a vacancy fitted to receive the species, there it operates with its whole effect; there it pours in its numbers and replenishes the waste. We complain of what we call the exorbitant multiplication of some troublesome insects; not reflecting, that large portions of nature might be left void without it. If the accounts of travellers may be depended upon, immense tracts of forests in North America would be nearly lost to sensitive existence, if it were not for *gnats*. "In the thinly inhabited regions of America, in which the waters stagnate and the climate is warm, the whole air is filled with crowds of these insects." Thus it is, that where we looked for solitude and death-like silence, we meet with animation, activity, enjoyment; with a busy, a happy, and a peopled world. Again; hosts of *mice* are reckoned amongst the plagues of the north-east part of Europe; whereas vast plains in Siberia, as we learn from good authority, would be lifeless without them. The Caspian deserts are converted by their presence into crowds of warrens. Between the Volga and the Yaik, and in the country of Hyrcania, the ground, says Pallas, is in many places *covered* with little hills, raised by the earth cast out in forming the burrows. Do we so envy these blissful abodes, as to pronounce the fecundity by which they are supplied with inhabitants to be an evil; a subject of complaint, and not of praise? Further; by virtue of this same superfecundity, what we term destruction becomes almost instantly the parent of life. What we call blights are oftentimes legions of animated beings, claiming their portion in the bounty of nature. What corrupts the produce of the earth to us, prepares it for them. And it is by means of their rapid multiplication, that they take possession of their pasture; a slow propagation would not meet the opportunity.

But in conjunction with the occasional use of this fruitfulness, we observe, also, that it allows the proportion between the several species of animals to be differently modified, as different purposes of utility may require. When the forests of America come to be cleared, and the swamps drained, our gnats will give place to other inhabitants. If the population of Europe should spread to the north and the east, the mice will retire before the husbandman and the shepherd, and yield their station to herds and flocks. In what concerns the human species, it may be a part of the scheme of Providence, that the earth should be inhabited by a shifting, or perhaps a circulating population. In this œconomy, it is possible that there may be the following advantages: When old countries are become exceedingly corrupt, simpler modes of life, purer morals, and better institutions, may rise up in new ones; whilst fresh soils reward the cultivator with more plentiful returns. Thus the different portions of the globe come into use in succession as the residence of man; and, in his absence, entertain other guests, which, by their sudden multiplication, fill the chasm. In domesticated animals, we find the effect of their fecundity to be, that we can always command *numbers*; we can always have as many of any particular species as we please, or as we can support. Nor do we complain of its excess; it being much more easy to regulate abundance, than to supply scarcity.

But then this *superfecundity*, though of great occasional use and importance, exceeds the ordinary capacity of nature to receive or support its progeny. All superabundance supposes destruction, or must destroy itself. Perhaps there is no species of terrestrial animals whatever, which would not overrun the earth, if it were permitted to multiply in perfect safety; or of fish, which would not fill the ocean: at least, if any single species were left to their natural increase without disturbance or restraint, the food of other species would be exhausted by their maintenance. It is necessary, therefore, that the effects of such prolific faculties be curtailed. In conjunction with other checks and limits, all subservient to the same purpose, are the *thinnings* which take place among animals, by their action upon one another. In some instances we ourselves experience, very directly, the use of these hostilities. One species of insects rids us of another species; or reduces their ranks. A third species, perhaps, keeps the second within bounds; and birds or lizards are a fence against the inordinate increase by which even these last might infest us. In other, more numerous, and possibly more important instances, this disposition of things, although less necessary or useful to us, and of course less observed by us, may be necessary and useful to certain other species; or even for the preventing of the loss of certain species from the universe: a misfortune which seems to be studiously guarded against. Though there may be the appearance of failure in some of the details of Nature's works, in her great purposes there never are. Her species never fail. The provision which was originally made for continuing the replenishment of the world has proved itself to be effectual through a long succession of ages.

What further shows, that the system of destruction amongst animals holds an express relation to the system of fecundity,—that they are parts indeed of one compensatory scheme,—is, that in each species the fecundity bears a proportion to the smallness of the animal, to the weakness, to the shortness of its natural term of life, and to the dangers and enemies by which it is surrounded. An elephant produces but one calf; a butterfly lays six hundred eggs. Birds of prey seldom produce more than two eggs: the sparrow tribe, and the duck tribe, frequently sit upon a dozen. In the rivers, we meet with a thousand minnows for one pike; in the sea, a million of herrings for a single shark. Compensation obtains throughout. Defencelessness and devastation are repaired by fecundity.

We have dwelt the longer on these considerations, because the subject to which they apply, namely that of animals *devouring* one another, forms the chief, if not the only instance, in the works of the Deity, of an œconomy, stamped by marks of design, in which the character of utility can be called in question. The case of *venomous* animals is of much inferior consequence to the case of prey, and, in some degree, is also included under it. To both cases it is probable that many more reasons belong, than those of which we are in possession.

Our FIRST PROPOSITION, and that which we have hitherto been defending, was, "that, in a vast plurality of instances, in which *contrivance* is perceived, the design of the contrivance is beneficial."

Our SECOND PROPOSITION is, "that the Deity has added *pleasure* to animal sensations, beyond what was necessary for any other purpose, or when the purpose, so far as it was necessary, might have been effected by the operation of pain."[29]

[29] This is a most important consideration, and one which cannot be dwelt upon too constantly; and which assuredly will, by the contemplative and well-regulated mind, never be dwelt upon without experiencing the most pleasing and salutary influence. It will be further illustrated in the Appendix; but in this place it may be right to add, that the induction of facts plainly shows the system of the universe to be governed upon the principle of inducement rather than denouncement; of reward more than of punishment; and not only are sentient beings guided by the more kindly process where the harsher would have sufficed, but there is more inducement employed, more pleasure superadded, than is even necessary to work the effect intended. It is as if a human lawgiver were to prefer rewarding his subjects for obedience, rather than punishing them for contumacy; and were then to add some bounty beyond what had been found quite sufficient to ensure their compliance. It must be constantly borne in mind, that there is not one single act performed by any animal, from man to the lowest insect in the scale, in fulfilling the apparent ends of its creation, the performance of which might not have been secured as effectually by the pressure or by

This proposition may be thus explained: The capacities, which, according to the established course of nature, are *necessary* to the support or preservation of an animal, however manifestly they may be the result of an organisation contrived for the purpose, can only be deemed an act or a part of the same will, as that which decreed the existence of the animal itself; because, whether the creation proceeded from a benevolent or a malevolent being, these capacities must have been given, if the animal existed at all. Animal properties, therefore, which fall under this description, do not strictly prove the goodness of God; they may prove the existence of the Deity; they may prove a high degree of power and intelligence: but they do not prove his goodness; forasmuch as they must have been found in any creation which was capable of continuance, although it is possible to suppose, that such a creation might have been produced by a being whose views rested upon misery.

But there is a class of properties, which may be said to be superadded from an intention expressly directed to happiness; an intention to

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the apprehension of pain, as it now is, in so vast a number of instances, solicited by the enjoyment or the hope of some gratification.

give a happy existence distinct from the general intention of providing the means of existence; and that is, of capacities for pleasure, in cases wherein, so far as the conservation of the individual or of the species is concerned, they were not wanted, or wherein the purpose might have been secured by the operation of pain. The provision which is made of a variety of objects, not necessary to life, and ministering only to our pleasures; and the properties given to the necessaries of life themselves, by which they contribute to pleasure as well as preservation; show a further design than that of giving existence.*

A single instance will make all this clear. Assuming the necessity of food for the support of animal life, it is requisite that the animal be provided with organs fitted for the procuring, receiving, and digesting of its food. It may also be necessary, that the animal be impelled by its sensations to exert its organs. But the pain of hunger would do all this. Why add pleasure to the act of eating; sweetness and relish to food? why a new and appropriate sense for the perception of the pleasure? Why should the juice of a

* See this topic considered in Dr. Balguy's Treatise upon the Divine Benevolence. This excellent author first, I think, proposed it; and nearly in the terms in which it is here stated. Some other observations also under this head are taken from that treatise.—*Note of the Author.*

peach, applied to the palate, affect the part so differently from what it does when rubbed upon the palm of the hand? This is a constitution which, so far as appears to me, can be resolved into nothing but the pure benevolence of the Creator. Eating is necessary; but the pleasure attending it is not necessary: and that this pleasure depends, not only upon our being in possession of the sense of taste, which is different from every other, but upon a particular state of the organ in which it resides, a felicitous adaptation of the organ to the object, will be confessed by any one, who may happen to have experienced that vitiation of taste which frequently occurs in fevers, when every taste is irregular, and every one bad.

In mentioning the gratifications of the palate, it may be said that we have made choice of a trifling example.[30] I am not of that opinion.

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[30] Neither this nor any other thing which our nature, physical or moral, is formed to relish, can be deemed trifling; and it is well observed afterwards that the very capacity of being pleased with what, by comparison with other things, are termed trivial matters, is itself a source of enjoyment provided for us by the divine beneficence. All men have within themselves the power of being amused or occupied, and interested—that is pleased, gratified—with things which, until they make the attempt,

They afford a share of enjoyment to man; but to brutes, I believe that they are of very great im-

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they are disposed to regard as wholly incapable of affording any satisfaction. This is a most important source of enjoyment, and one more independent of external circumstances than they could believe who have never made the experiment. "Le goût (says Marmontel, *Mêm.* I. 431) s'accommode aux objets dont il peut jouir; et cette sage maxime,

Quand on n'a pas ce que l'on aime,
Il faut aimer ce que l'on a,

est en effet non seulement une leçon de la nature, mais un moyen qu'elle se ménage pour nous procurer des plaisirs." The earlier and by far the most interesting part of his book abounds in illustrations of a kindred truth —the gratification derived from the humblest sources by those who have known none other. "Nos galettes de sarrazin, humectées, toutes brûlantes, de ce bon beurre du Mont-d'or, étaient pour nos le plus friaud régal. Je ne sais pas quel mets nous eût paru meilleur que nos raves et nos châtaignes; et en hiver, lorsque ces belles raves grillaient le soir à l'entour du foyer, ou que nous entendions bouillonner l'eau du vase où cuisaient ces châtaignes si savoureuses et si douces, le cœur nous palpitait de joie."—(Ib. p. 9.) "Quand j'arrivais chez moi, et que, dans un bon lit ou au coin d'un bon feu, je me sentais tout ranimê, c'était pour moi l'un des moments les plus délicieux de la vie; jouissance que la mollesse ne m'aurait jamais fait connaître."—(Ib. 34.)

portance. A horse at liberty passes a great part of his waking hours in eating. To the ox, the sheep, the deer, and other ruminating animals, the pleasure is doubled. Their whole time almost is divided between browsing upon their pasture and chewing their cud. Whatever the pleasure be, it is spread over a large portion of their existence. If there be animals, such as the lupous fish, which swallow their prey whole, and at once, without any time, as it should seem, for either drawing out, or relishing, the taste in the mouth, is it an improbable conjecture, that the seat of taste with them is in the stomach; or, at least, that a sense of pleasure, whether it be taste or not, accompanies the dissolution of the food in that receptacle, which dissolution in general is carried on very slowly? If this opinion be right, they are more than repaid for the defect of palate. The feast lasts as long as the digestion.

In seeking for argument, we need not stay to insist upon the comparative importance of our example; for the observation holds equally of all, or of three at least, of the other senses. The necessary purposes of hearing might have been answered without harmony; of smell, without fragrance; of vision, without beauty. Now, "if the Deity had been indifferent about our happiness or misery, we must impute to our good fortune (as all design by this supposition is excluded), both the capacity of our senses to receive pleasure, and the supply of external objects fitted to excite it." I allege these as *two* felicities, for they are different things, yet both necessary: the sense being formed, the objects, which were applied to it, might not have suited it; the objects being fixed, the sense might not have agreed with them. A coincidence is here required, which no accident can account for. There are three possible suppositions upon the subject, and no more. The first; that the sense, by its original constitution, was made to suit the object: The second; that the object, by its original constitution, was made to suit the sense: The third; that the sense is so constituted, as to be able, either universally, or within certain limits, by habit and familiarity, to render every object pleasant. Whichever of these suppositions we adopt, the effect evinces, on the part of the Author of nature, a studious benevolence. If the pleasures which we derive from any of our senses depend upon an original congruity between the sense and the properties perceived by it, we know by experience that the adjustment demanded, with respect to the qualities which were conferred upon the objects that surround us, not only choice and selection, out of a boundless variety of possible qualities with which these objects might have been endued, but a *proportioning also of degree*, because an excess or defect of intensity spoils the perception, as much almost as an error in the kind and nature of the quality. Likewise the degree of dulness or acuteness in the sense itself is no arbitrary thing, but, in order to preserve the congruity here spoken of, requires to be in an exact or near correspondency with the strength of the impression. The dulness of the senses forms the complaint of old age. Persons in fevers, and, I believe, in most maniacal cases, experience great torment from their preternatural acuteness. An increased, no less than an impaired sensibility, induces a state of disease and suffering.

The doctrine of a specific congruity between animal senses and their objects is strongly favoured by what is observed of insects in the election of their food. Some of these will feed upon one kind of plant or animal, and upon no other: some caterpillars upon the cabbage alone; some upon the black currant alone. The species of caterpillar which eats the vine will starve upon the alder; nor will that which we find upon fennel touch the rose-bush. Some insects confine themselves to two or three kinds of plants or animals. Some again show so strong a preference as to afford reason to believe that, though they may be driven by hunger to others, they are led by the pleasure of taste to a few particular plants alone; and all this, as it should seem, independently of habit or imitation.

But should we accept the third hypothesis, and even carry it so far as to ascribe every thing which concerns the question to habit (as in certain species, the human species most particularly, there is reason to attribute something), we have then before us an animal capacity, not less perhaps to be admired than the native congruities which the other scheme adopts. It cannot be shown to result from any fixed necessity in nature, that what is frequently applied to the senses should of course become agreeable to them. It is, so far as it subsists, a power of accommodation provided in these senses by the Author of their structure, and forms a part of their perfection.

In whichever way we regard the senses, they appear to be specific gifts, ministering, not only to preservation, but to pleasure. But what we usually call the *senses*, are probably themselves far from being the only vehicles of enjoyment, or the whole of our constitution which is calculated for the same purpose. We have many internal sensations of the most agreeable kind, hardly referable to any of the five senses. Some physiologists have holden that all secretion is pleasurable; and that the complacency which in health, without any external assignable object to excite it, we derive from life itself, is the effect of our secretions going on well within us. All this may be true; but if true, what reason can be assigned for it, except the will of the Creator? It may reasonably be asked, Why is any thing a pleasure? and I know no answer which can be returned to the question, but that which refers it to appointment.

We can give no account whatever of our pleasures in the simple and original perception; and, even when physical sensations are assumed, we can seldom account for them in the secondary and complicated shapes in which they take the name of diversions. I never yet met with a sportsman, who could tell me in what the sport consisted; who could resolve it into its principle, and state that principle. I have been a great follower of fishing myself, and in its cheerful solitude have passed some of the happiest hours of a sufficiently happy life; but, to this moment, I could never trace out the source of the pleasure which it afforded me.

The "quantum in rebus inane!" whether applied to our amusements or to our graver pursuits, (to which, in truth, it sometimes equally belongs,) is always an unjust complaint. If trifles engage, and if trifles make us happy, the true reflection suggested by the experiment is upon the tendency of nature to gratification and enjoyment; which is, in other words, the goodness of its Author towards his sensitive creation.

Rational natures also, as such, exhibit qualities which help to confirm the truth of our position. The degree of understanding found in mankind is usually much greater than what is necessary for mere preservation. The pleasure of choosing for themselves, and of prosecuting the object of their choice, should seem to be an original source of enjoyment. The pleasures received from things, great, beautiful, or new, from imitation, or from the liberal arts, are, in some measure, not only superadded, but unmixed, gratifications, having no pains to balance them.*

I do not know whether our attachment to *property* be not something more than the mere dictate of reason, or even than the mere effect of association. Property communicates a charm to whatever is the object of it. It is the first of our abstract ideas; it cleaves to us the closest and the longest. It endears to the child its plaything, to the peasant his cottage, to the landholder his estate. It supplies the place of prospect and scenery. Instead of coveting the beauty of dis-

* Balguy on the Divine Benevolence.

tant situations, it teaches every man to find it in his own. It gives boldness and grandeur to plains and fens, tinge and colouring to clays and fallows.

All these considerations come in aid of our *second* proposition. The reader will now bear in mind what our two propositions were. They were, firstly, that in a vast plurality of instances, in which contrivance is perceived, the design of the contrivance is beneficial: secondly, that the Deity has added pleasure to animal sensations beyond what was necessary for any other purpose; or when the purpose, so far as it was necessary, might have been effected by the operation of pain.

Whilst these propositions can be maintained, we are authorised to ascribe to the Deity the character of benevolence; and what is benevolence at all, must in him be *infinite* benevolence, by reason of the infinite, that is to say, the incalculably great, number of objects upon which it is exercised.

Of the ORIGIN OF EVIL no universal solution has been discovered; I mean, no solution which reaches to all cases of complaint. The most comprehensive is that which arises from the consideration of *general rules*.[31] We may, I think, without

[31] These observations on General Laws, and those

much difficulty, be brought to admit the four following points: first, that important advantages may accrue to the universe from the order of nature proceeding according to general laws: secondly, that general laws, however well set and constituted, often thwart and cross one another: thirdly, that from these thwartings and crossings, frequent particular inconveniences will arise: and, fourthly, that it agrees with our observation to suppose, that some degree of these inconveniences

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which follow upon the doctrine of Imperfections, have been misunderstood, in the same way with the former remarks, referred to in the second note upon this chapter; but it must be allowed that the expressions here used respecting General Laws are somewhat incautious, and more liable to cavil. Nevertheless, the whole scope of the argument which follows plainly shows that our author never thought of solving the difficulty as to evil by resorting to the existence of laws, which are themselves only the modes of acting pursued by the Deity himself. In truth this portion of his argument is, like that on which we formerly commented, only to be considered as stating a deduction to be made from the total amount of evil; in other words, the reasoning is only a reduction of the apparent quantity to the real. Anything beyond this would really be recurring to the ancient doctrine of the heathens, whose gods were limited in power and controlled by fate.

takes place in the works of nature. These points may be allowed; and it may also be asserted, that the general laws with which we are acquainted are directed to beneficial ends. On the other hand, with many of these laws we are not acquainted at all, or we are totally unable to trace them in their branches, and in their operation; the effect of which ignorance is, that they cannot be of importance to us as measures by which to regulate our conduct. The conservation of them may be of importance in other respects, or to other beings, but we are uninformed of their value or use; uninformed consequently, when, and how far, they may or may not be suspended, or their effects turned aside, by a presiding and benevolent will, without incurring greater evils than those which would be avoided. The consideration, therefore, of general laws, although it may concern the question of the origin of evil very nearly (which I think it does), rests in views disproportionate to our faculties, and in a knowledge which we do not possess. It serves rather to account for the obscurity of the subject, than to supply us with distinct answers to our difficulties. However, whilst we assent to the above-stated propositions, as principles, whatever uncertainty we may find in the application, we lay a ground for believing, that cases of apparent evil, for which *we* can suggest no particular reason, are governed by reasons, which are more general, which lie deeper in the order of second causes, and which on that account are removed to a greater distance from us.

The doctrine of *imperfections*, or, as it is called, of evils of imperfection, furnishes an account, founded, like the former, in views of universal nature. The doctrine is briefly this:—It is probable, that creation may be better replenished by sensitive beings of different sorts, than by sensitive beings all of one sort. It is likewise probable, that it may be better replenished by different orders of beings rising one above another in gradation, than by beings possessed of equal degrees of perfection. Now, a gradation of such beings implies a gradation of imperfections. No class can justly complain of the imperfections which belong to its place in the scale, unless it were allowable for it to complain, that a scale of being was appointed in nature; for which appointment there appear to be reasons of wisdom and goodness.

In like manner *finiteness*, or what is resolvable into finiteness, in inanimate subjects, can never be a just subject of complaint; because if it were ever so, it would be always so: we mean, that we can never reasonably demand that things should be larger or more, when the same demand might be made, whatever the quantity or number was.

And to me it seems that the sense of mankind has so far acquiesced in these reasons, as that we seldom complain of evils of this class, when we clearly perceive them to be such. What I have to add, therefore, is, that we ought not to complain of some other evils, which stand upon the same foot of vindication as evils of confessed imperfection. We never complain, that the globe of our earth is too small: nor should we complain, if it were even much smaller. But where is the difference to us, between a less globe, and part of the present being uninhabitable? The inhabitants of an island may be apt enough to murmur at the sterility of some parts of it, against its rocks, or sands, or swamps: but no one thinks himself authorised to murmur, simply because the island is not larger than it is. Yet these are the same griefs.

The above are the two metaphysical answers which have been given to this great question. They are not the worse for being metaphysical, provided they be founded (which I think they are) in right reasoning: but they are of a nature too wide to be brought under our survey, and it is often difficult to apply them in the detail. Our speculations, therefore, are perhaps better employed when they confine themselves within a narrower circle.

The observations which follow are of this more limited, but more determinate, kind.

Of *bodily pain*, the principal observation, no doubt, is that which we have already made, and already dwelt upon, *viz.* "that it is seldom the object of contrivance; that when it is so, the contrivance rests ultimately in good."

To which, however, may be added, that the annexing of pain to the means of destruction is a salutary provision; inasmuch as it teaches vigilance and caution; both gives notice of danger, and excites those endeavours which may be necessary to preservation. The evil consequence, which sometimes arises from the want of that timely intimation of danger which pain gives, is known to the inhabitants of cold countries by the example of frost-bitten limbs. I have conversed with patients who had lost toes and fingers by this cause. They have in general told me, that they were totally unconscious of any local uneasiness at the time. Some I have heard declare, that, whilst they were about their employment, neither their situation, nor the state of the air, was unpleasant. They felt no pain; they suspected no mischief; till, by the application of warmth, they discovered, too late, the fatal injury which some of their extremities had suffered. I say that this shows the use of pain, and that we stand in need of such a monitor. I believe also that the use extends farther than we suppose, or can now trace; that to disagreeable sensations we, and all animals, owe, or have owed, many habits of action which are salutary, but which are become so familiar, as not easily to be referred to their origin.

[33] PAIN also itself is not without its *alleviations*. It may be violent and frequent; but it is seldom both violent and long-continued: and its pauses and intermissions become positive pleasures. It has the power of shedding a satisfaction over intervals of ease, which, I believe, few enjoyments exceed. A man resting from a fit of the stone or gout, is, for the time, in possession of feelings which undisturbed health cannot impart. They

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[33] This chapter, we are told by Dr. Fenwick in his sketch of Dr. Clark's life, "was written when Dr. Paley was suffering under severe attacks of a painful disorder under which he had long laboured, and which afterwards proved fatal." Dr. Fenwick justly remarks upon the additional interest which this circumstance communicates to the author's remarks upon the interruptions of pain.—Meadly's Memoirs of Paley, p. 204.

may be dearly bought, but still they are to be set against the price. And, indeed, it depends upon the duration and urgency of the pain, whether they be dearly bought or not. I am far from being sure, that a man is not a gainer by suffering a moderate interruption of bodily ease for a couple of hours out of the four-and-twenty. Two very common observations favour this opinion: one is, that remissions of pain call forth, from those who experience them, stronger expressions of satisfaction and of gratitude towards both the author and the instruments of their relief, than are excited by advantages of any other kind: the second is, that the spirits of sick men do not sink in proportion to the acuteness of their sufferings; but rather appear to be roused and supported, not by pain, but by the high degree of comfort which they derive from its cessation, or even its subsidency, whenever that occurs; and which they taste with a relish, that diffuses some portion of mental complacency over the whole of that mixed state of sensations in which disease has placed them.

In connexion with bodily pain may be considered bodily *disease*, whether painful or not. Few diseases are fatal. I have before me the account of a dispensary in the neighbourhood, which states six years' experience as follows:—

Admitted	. . . . .	6,420
Cured	. . . . . .	5,476
Dead	. . . . . .	234

And this I suppose nearly to agree with what other similar institutions exhibit. Now, in all these cases, some disorder must have been felt, or the patients would not have applied for a remedy; yet we see how large a proportion of the maladies which were brought forward have either yielded to proper treatment, or, what is more probable, ceased of their own accord. We owe these frequent recoveries, and, where recovery does not take place, this patience of the human constitution under many of the distempers by which it is visited, to two benefactions of our nature. One is, that she works within certain limits; allows of a certain latitude within which health may be preserved, and within the confines of which it only suffers a graduated diminution. Different quantities of food, different degrees of exercise, different portions of sleep, different states of the atmosphere, are compatible with the possession of health. So likewise it is with the secretions and excretions, with many internal functions of the body, and with the state, probably, of most of its internal organs. They may vary considerably, not only without destroying life, but without occasioning any high degree of inconveniency. The other property of our nature, to which we are still more beholden, is its constant endeavour to restore itself, when disordered, to its regular course. The fluids of the body appear to possess a power of separating and expelling any noxious substance which may have mixed itself with them. This they do, in eruptive fevers, by a kind of despumation, as Sydenham calls it, analogous in some measure to the intestine action by which fermenting liquors work the yest to the surface. The solids, on their part, when their action is obstructed, not only resume that action, as soon as the obstruction is removed, but they struggle with the impediment. They take an action as near to the true one, as the difficulty and the disorganisation with which they have to contend will allow of.

Of *mortal* diseases, the great use is to reconcile us to death. The horror of death proves the value of life. But it is in the power of disease to abate, or even extinguish, this horror; which it does in a wonderful manner, and, oftentimes, by a mild and imperceptible gradation. Every man who has been placed in a situation to observe it, is surprised with the change which has been wrought in himself, when he compares the view which he entertains of death upon a sick-bed, with the heart-sinking dismay with which he should some time ago have met it in health. There is no similitude between the sensations of a man led to execution, and the calm expiring of a patient at the close of his disease. Death to him is only the last of a long train of changes; in his progress through which, it is possible that he may experience no shocks or sudden transitions.

Death itself, as a mode of removal and of succession, is so connected with the whole order of our animal world, that almost every thing in that world must be changed, to be able to do without it. It may seem likewise impossible to separate the fear of death from the enjoyment of life, or the perception of that fear from rational natures. Brutes are in a great measure delivered from all anxiety on this account by the inferiority of their faculties; or rather they seem to be armed with the apprehension of death just sufficiently to put them upon the means of preservation, and no farther. But would a human being wish to purchase this immunity at the expense of those mental powers which enable him to look forward to the future?

Death implies *separation:* and the loss of those whom we love must necessarily, so far as we can conceive, be accompanied with pain. To the brute creation, nature seems to have stepped in with some secret provision for their relief, under the rupture of their attachments. In their instincts towards their offspring, and of their offspring to them, I have often been surprised to observe how ardently they love, and how soon they forget. The pertinacity of human sorrow (upon which time also, at length, lays its softening hand) is probably, therefore, in some manner connected with the qualities of our rational or moral nature. One thing however is clear, *viz.* that it is better that we should possess affections, the sources of so many virtues, and so many joys, although they be exposed to the incidents of life, as well as the interruptions of mortality, than, by the want of them, be reduced to a state of selfishness, apathy, and quietism.[33]

Of other external evils (still confining ourselves to what are called physical or natural evils), a considerable part come within the scope of the following observation:—The great principle of human satisfaction is *engagement.* It is a most just distinction, which the late Mr. Tucker has dwelt upon so largely in his works, between pleasures in which we are passive, and pleasures in which we are active. And, I believe, every attentive observer of human life will assent to his po-

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[33] The remarks made in the two former notes (2 and 31) are applicable to this part of the text also.

sition, that, however grateful the sensations may occasionally be in which we are passive, it is not these, but the latter class of our pleasures, which constitute satisfaction; which supply that regular stream of moderate and miscellaneous enjoyments, in which happiness, as distinguished from voluptuousness, consists. Now for rational occupation, which is, in other words, for the very material of contented existence, there would be no place left, if either the things with which we had to do were absolutely impracticable to our endeavours, or if they were too obedient to our uses. A world, furnished with advantages on one side, and beset with difficulties, wants, and inconveniences on the other, is the proper abode of free, rational, and active natures, being the fittest to stimulate and exercise their faculties. The very *refractoriness* of the objects they have to deal with, contributes to this purpose. A world in which nothing depended upon ourselves, however it might have suited an imaginary race of beings, would not have suited mankind. Their skill, prudence, industry; their various arts and their best attainments, from the application of which they draw, if not their highest, their most permanent gratifications, would be insignificant, if things could be either moulded by our volitions, or, of their own accord, conformed themselves to our views and wishes. Now it is in this refractoriness that we discern the seed and principle of *physical* evil, as far as it arises from that which is external to us.

Civil evils,[34] or the evils of civil life, are much more easily disposed of, than physical evils: because they are, in truth, of much less magnitude, and also because they result, by a kind of necessity, not only from the constitution of our nature, but from a part of that constitution which no one would wish to see altered. The case is this: Mankind will in every country *breed up* to a certain point of distress. That point may be different in different countries or ages, according to the established usages of life in each. It will also shift upon the scale, so as to admit of a greater or less number of inhabitants, according as the quantity of provision, which is either produced in the country, or supplied to it from other countries,

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[34] In all arguments respecting civil and political evils it is important to keep the distinction steadily in view between contentment under necessary sufferings, and quietism under such as may be avoided by improvements in our institutions. Contentment, indeed, under even the latter, is a virtue as well as a solace, during the period required for their safe and legitimate amendment; but this is no exception to the rule which we have glanced at; for the sufferings must be considered necessary until their removal can be safely effected.

may happen to vary. But there must always be such a point, and the species will always breed up to it. The order of generation proceeds by something like a geometrical progression. The increase of provision, under circumstances even the most advantageous, can only assume the form of an arithmetic series. Whence it follows that the population will always overtake the provision, will pass beyond the line of plenty, and will continue to increase till checked by the difficulty of procuring subsistence.* Such difficulty therefore, along with its attendant circumstances, *must* be found in every old country; and these circumstances constitute what we call poverty, which necessarily imposes labour, servitude, restraint.

It seems impossible to people a country with inhabitants who shall be all easy in circumstances. For suppose the thing to be done, there would be such marrying and giving in marriage amongst them, as would in a few years change the face of affairs entirely: *i. e.* as would increase the consumption of those articles which supplied the natural or habitual wants of the country to such a degree of scarcity, as must leave the greatest part of the inhabitants unable to procure them with-

* See a statement of this subject in a late treatise upon population.—*Note of the Author.*

out toilsome endeavours; or, out of the different kinds of these articles, to procure any kind except that which was most easily produced. And this, in fact, describes the condition of the mass of the community in all countries: a condition unavoidably, as it should seem, resulting from the provision which is made in the human, in common with all animal constitutions, for the perpetuity and multiplication of the species.

It need not however dishearten any endeavours for the public service, to know that population naturally treads upon the heels of improvement. If the condition of a people be meliorated, the consequence will be, either that the *mean* happiness will be increased, or a greater number partake of it; or, which is most likely to happen, that both effects will take place together. There may be limits fixed by nature to both, but they are limits not yet attained, nor even approached, in any country of the world.

And when we speak of limits at all, we have respect only to provisions for animal wants. There are sources, and means, and auxiliaries, and augmentations of human happiness, communicable without restriction of numbers; as capable of being possessed by a thousand persons as by one. Such are those which flow from a mild, contrasted with a tyrannic government, whether civil or domestic; those which spring from religion; those which grow out of a sense of security; those which depend upon habits of virtue, sobriety, moderation, order; those, lastly, which are found in the possession of well-directed tastes and desires, compared with the dominion of tormenting, pernicious, contradictory, unsatisfied and unsatisfiable passions.

The *distinctions* of civil life are apt enough to be regarded as evils by those who sit under them; but, in my opinion, with very little reason.

In the first place, the advantages which the higher conditions of life are supposed to confer bear no proportion in value to the advantages which are bestowed by nature. The gifts of nature always surpass the gifts of fortune. How much, for example, is activity better than attendance; beauty than dress; appetite, digestion, and tranquil bowels, than all the studies of cookery, or than the most costly compilation of forced or far-fetched dainties!

Nature has a strong tendency to equalisation. Habit, the instrument of nature, is a great leveller; the familiarity which it induces taking off the edge both of our pleasures and our sufferings. Indulgences which are habitual, keep us in ease, and cannot be carried much farther. So that with respect to the gratifications of which the senses are capable, the difference is by no means proportionable to the apparatus. Nay, so far as superfluity generates fastidiousness, the difference is on the wrong side.

It is not necessary to contend, that the advantages derived from wealth are none (under due regulations they are certainly considerable), but that they are not greater than they ought to be. *Money* is the sweetener of human toil; the substitute for coercion; the reconciler of labour with liberty. It is, moreover, the stimulant of enterprise in all projects and undertakings, as well as of diligence in the most beneficial arts and employments. Now, did affluence, when possessed, contribute nothing to happiness, or nothing beyond the mere supply of necessaries,—and the secret should come to be discovered,—we might be in danger of losing great part of the uses which are at present derived to us through this important medium. Not only would the tranquillity of social life be put in peril by the want of a motive to attach men to their private concerns; but the satisfaction which all men receive from success in their respective occupations, which collectively constitutes the great mass of human comfort, would be done away in its very principle.

With respect to *station*, as it is distinguished from riches, whether it confer authority over others, or be invested with honours which apply solely to sentiment and imagination, the truth is that what is gained by rising through the ranks of life, is not more than sufficient to draw forth the exertions of those who are engaged in the pursuits which lead to advancement, and which, in general, are such as ought to be encouraged. Distinctions of this sort are subjects much more of competition than of enjoyment; and in that competition their use consists. It is not, as hath been rightly observed, by what the *Lord Mayor* feels in his coach, but by what the *apprentice* feels who gazes at him, that the public is served.

As we approach the summits of human greatness, the comparison of good and evil, with respect to personal comfort, becomes still more problematical; even allowing to ambition all its pleasures. The poet asks, "What is grandeur, what is power?" The philosopher answers, "Constraint and plague: *et in maximâ quâque fortunâ minimum licere*." One very common error misleads the opinion of mankind on this head, *viz.* that, universally, authority is pleasant, submission painful. In the general course of human affairs, the very reverse of this is nearer the truth. Command is anxiety, obedience ease.

Artificial distinctions sometimes promote real equality, Whether they be hereditary, or be the homage paid to office, or the respect attached by public opinion to particular professions, they serve to *confront* that grand and unavoidable distinction which arises from property, and which is most overbearing where there is no other. It is of the nature of property, not only to be irregularly distributed, but to run into large masses. Public laws should be so constructed as to favour its diffusion as much as they can. But all that can be done by laws, consistently with that degree of government of his property which ought to be left to the subject, will not be sufficient to counteract this tendency. There must always, therefore, be the difference between rich and poor; and this difference will be the more grinding when no pretension is allowed to be set up against it.

So that the evils, if evils they must be called, which spring either from the necessary subordinations of civil life, or from the distinctions which have naturally, though not necessarily, grown up in most societies, so long as they are unaccompanied by privileges injurious or oppressive to the rest of the community, are such as may, even by the most depressed ranks, be endured with very little prejudice to their comfort.

The mischiefs of which mankind are the occasion to one another, by their private wickednesses and cruelties; by tyrannical exercises of power; by rebellions against just authority; by wars; by national jealousies and competitions operating to the destruction of third countries; or by other instances of misconduct either in individuals or societies, are all to be resolved into the character of man as a *free agent.* Free agency, in its very essence, contains liability to abuse. Yet, if you deprive man of his free agency, you subvert his nature. You may have order from him and regularity, as you may from the tides or the trade-winds, but you put an end to his moral character, to virtue, to merit, to accountableness, to the use indeed of reason. To which must be added the observation, that even the bad qualities of mankind have an origin in their good ones. The case is this: Human passions are either necessary to human welfare, or capable of being made, and, in a great majority of instances, in fact made, conducive to its happiness. These passions are strong and general; and, perhaps, would not answer their purpose unless they were so. But strength and generality, when it is expedient that particular circumstances should be respected, become, if left to themselves, excess and misdirection. From which excess and misdirection, the vices of mankind (the causes, no doubt, of much misery) appear to spring. This account, whilst it shows us the principle of vice, shows us, at the same time, the province of reason and of self-government; the want also of every support which can be procured to either from the aids of religion; and it shows this, without having recourse to any native, gratuitous malignity in the human constitution. Mr. Hume, in his posthumous dialogues, asserts, indeed, of *idleness*, or aversion to labour (which he states to lie at the root of a considerable part of the evils which mankind suffer), that it is simply and merely bad. But how does he distinguish idleness from the love of ease? or is he sure, that the love of ease in individuals is not the chief foundation of social tranquillity? It will be found, I believe, to be true, that in every community there is a large class of its members, whose idleness is the best quality about them, being the corrective of other bad ones. If it were possible, in every instance, to give a right determination to industry, we could never have too much of it. But this is not possible, if men are to be free. And without this, nothing would be so dangerous, as an incessant, universal, indefatigable activity. In the civil world, as well as in the material, it is the *vis inertiæ* which keeps things in their places.

Natural Theology has ever been pressed with this question,—Why, under the regency of a supreme and benevolent Will, should there be in the world so much as there is of the appearance of *chance?*

The question in its whole compass lies beyond our reach: but there are not wanting, as in the origin of evil, answers which seem to have considerable weight in particular cases, and also to embrace a considerable number of cases.

I. There must be *chance* in the midst of design: by which we mean, that events which are not designed, necessarily arise from the pursuit of events which are designed. One man travelling to York, meets another man travelling to London. Their meeting is by chance, is accidental, and so would be called and reckoned, though the journeys which produced the meeting were, both of them, undertaken with design and from deliberation. The meeting, though accidental, was nevertheless hypothetically necessary (which is the only sort of necessity that is intelligible): for if the two journeys were commenced at the time, pursued in the direction, and with the speed, in which and with which, they were in fact begun and performed, the meeting could not be avoided. There was not, therefore, the less necessity in it for its being by chance. Again, the rencounter might be most unfortunate, though the errand, upon which each party set out upon his journey, were the most innocent or the most laudable. The by effect may be unfavourable, without impeachment of the proper purpose, for the sake of which the train, from the operation of which these consequences ensued, was put in motion. Although no cause act without a good purpose, accidental consequences, like these, may be either good or bad.

II. The *appearance of chance* will always bear a proportion to the ignorance of the observer. The cast of a die as regularly follows the laws of motion, as the going of a watch; yet, because we can trace the operation of those laws through the works and movements of the watch, and cannot trace them in the shaking or throwing of the die (though the laws be the same, and prevail equally in both cases), we call the turning up of the number of the die, chance, the pointing of the index of the watch, machinery, order, or by some name which excludes chance. It is the same in those events which depend upon the will of a free and rational agent. The verdict of a jury, the sentence of a judge, the resolution of an assembly, the issue of a contested election, will have more or less the appearance of chance, might be more or less the subject of a wager, according as we were less or more acquainted with the reasons which influenced the deliberation. The difference resides in the information of the observer, and not in the thing itself; which, in all the cases proposed, proceeds from intelligence, from mind, from counsel, from design.[35]

Now when this one cause of the appearance of chance, *viz.* the ignorance of the observer, comes to be applied to the operations of the Deity, it is easy to foresee how fruitful it must prove of difficulties and of seeming confusion. It is only to think of the Deity, to perceive what variety of objects, what distance of time, what extent of space and action, his counsels may, or rather must, comprehend. Can it be wondered at, that, of the purposes which dwell in such a mind as this, so small a part should be known to us? It is only necessary, therefore, to bear in our thought, that in proportion to the inadequateness of our information, will be the quantity in the world of apparent chance.

III. In a great variety of cases, and of cases comprehending numerous subdivisions, it appears, for many reasons, to be better that events rise up by *chance*, or, more properly speaking, with the

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[35] See note to page 80 of the former volume respecting Chance. This paragraph is wholly free from the inaccuracy taken notice of in the former note.

appearance of chance, than according to any observable rule whatever. This is not seldom the case even in human arrangements. Each person's place and precedency, in a public meeting, may be determined by *lot*. Work and labour may be *allotted*. Tasks and burdens may be *allotted*:

——— Operumque laborem
Partibus æquabat justis, aut *sorte* trahebat.

Military service and station may be *allotted*. The distribution of provision may be made by *lot*, as it is in a sailor's mess; in some cases also, the distribution of favours may be made by *lot*. In all these cases, it seems to be acknowledged, that there are advantages in permitting events to chance superior to those which would or could arise from regulation. In all these cases also, though events rise up in the way of chance, it is by appointment that they do so.

In other events, and such as are independent of human will, the reasons for this preference of uncertainty to rule appear to be still stronger. For example: it seems to be expedient that the period of human life should be *uncertain*. Did mortality follow any fixed rule, it would produce a security in those that were at a distance from it, which would lead to the greatest disorders; and a horror in those who approached it, similar to that which a condemned prisoner feels on the night before his execution. But, that death be uncertain, the young must sometimes die, as well as the old. Also were deaths never *sudden*, they who are in health would be too confident of life. The strong and the active, who want most to be warned and checked, would live without apprehension or restraint. On the other hand, were sudden deaths very frequent, the sense of constant jeopardy would interfere too much with the degree of ease and enjoyment intended for us; and human life be too precarious for the business and interests which belong to it. There could not be dependence either upon our own lives, or the lives of those with whom we were connected, sufficient to carry on the regular offices of human society. The manner, therefore, in which death is made to occur, conduces to the purposes of admonition, without overthrowing the necessary stability of human affairs.[36]

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[36] It must never be forgotten that, according to the scheme, whether of Natural or of Revealed Religion, the doctrine of a Future State removes one branch of the evil here treated of, and answers the common sceptical objection grounded upon the destruction of one being made the means of benefit to another. In the view of religion, the person removed by Providence is to be considered as suffering no loss whatever,—he is at once taken to a superior state. The survivors alone are to be considered as regards the question of evil.

Disease being the forerunner of death, there is the same reason for its attacks coming upon us under the appearance of chance, as there is for uncertainty in the time of death itself.

The *seasons* are a mixture of regularity and chance. They are regular enough to authorise expectation, whilst their being, in a considerable degree, irregular, induces, on the part of the cultivators of the soil, a necessity for personal attendance, for activity, vigilance, precaution. It is this necessity which creates farmers; which divides the profit of the soil between the owner and the occupier; which by requiring expedients, by increasing employment, and by rewarding expenditure, promotes agricultural arts and agricultural life, of all modes of life the best, being the most conducive to health, to virtue, to enjoyment. I believe it to be found in fact, that where the soil is the most fruitful, and the seasons the most constant, there the condition of the cultivators of the earth is the most depressed. Uncertainty, therefore, has its use even to those who sometimes complain of it the most. Seasons of scarcity themselves are not without their advantages.[27] They call forth new exertions; they set contrivance

[27] See former note upon the only legitimate application of such arguments.

and ingenuity at work: they give birth to improvements in agriculture and œconomy; they promote the investigation and management of public resources.

Again: there are strong intelligible reasons, why there should exist in human society great disparity of *wealth* and *station;* not only as these things are acquired in different degrees, but at the first setting out of life. In order, for instance, to answer the various demands of civil life, there ought to be amongst the members of every civil society a diversity of education, which can only belong to an original diversity of circumstances. As this sort of disparity, which ought to take place from the beginning of life, must, *ex hypothesi,* be previous to the merit or demerit of the persons upon whom it falls, can it be better disposed of than by chance? *Parentage* is that sort of chance: yet it is the commanding circumstance which in general fixes each man's place in civil life, along with every thing which appertains to its distinctions. It may be the result of a beneficial rule, that the fortunes or honours of the father devolve upon the son; and, as it should seem, of a still more necessary rule, that the low or laborious condition of the parent be communicated to his family; but with respect to the successor himself, it is the drawing of a ticket in a lottery. Inequalities, therefore, of fortune, at least the greatest part of them, *viz.* those which attend us from our birth, and depend upon our birth, may be left, as they are left, to *chance*, without any just cause for questioning the regency of a supreme Disposer of events.

But not only the donation, when by the necessity of the case they must be gifts, but even the *acquirability* of civil advantages, ought perhaps, in a considerable degree, to lie at the mercy of chance. Some would have all the virtuous rich, or, at least, removed from the evils of poverty, without perceiving, I suppose, the consequence, that all the poor must be wicked. And how such a society could be kept in subjection to government, has not been shown: for the poor, that is, they who seek their subsistence by constant manual labour, must still form the mass of the community; otherwise the necessary labour of life could not be carried on; the work could not be done, which the wants of mankind in a state of civilization, and still more in a state of refinement, require to be done.

It appears to be also true, that the exigencies of social life call not only for an original diversity of *external* circumstances, but for a mixture of different faculties, tastes, and tempers. Activity and contemplation, restlessness and quiet, courage and timidity, ambition and contentedness, not to say even indolence and dulness, are all wanted in the world, all conduce to the well going on of human affairs, just as the rudder, the sails, and the ballast of a ship, all perform their part in the navigation. Now, since these characters require for their foundation different original talents, different dispositions, perhaps also different bodily constitutions; and since, likewise, it is apparently expedient, that they be promiscuously scattered amongst the different classes of society,—can the distribution of talents, dispositions, and the constitutions upon which they depend, be better made than by *chance?*

The *opposites* of apparent chance, are constancy and sensible interposition; every degree of *secret* direction being consistent with it. Now of *constancy*, or of fixed and known rules, we have seen in some cases the inapplicability; and inconveniences which we do not see, might attend their application in other cases.

Of *sensible* interposition, we may be permitted to remark, that a Providence, always and certainly distinguishable, would be neither more nor less than miracles rendered frequent and common. It is difficult to judge of the state into which this would throw us. It is enough to say, that it would cast us upon a quite different dispensation from that under which we live. It would be a total and radical change. And the change would deeply affect, or perhaps subvert, the whole conduct of human affairs. I can readily believe, that, other circumstances being adapted to it, such a state might be better than our present state. It may be the state of other beings; it may be ours hereafter. But the question with which we are now concerned is, how far it would be consistent with our condition, supposing it in other respects to remain as it is? And in this question there seem to be reasons of great moment on the negative side. For instance: so long as bodily labour continues, on so many accounts, to be necessary for the bulk of mankind, any dependency upon supernatural aid, by unfixing those motives which promote exertion, or by relaxing those habits which engender patient industry, might introduce negligence, inactivity, and disorder, into the most useful occupations of human life; and thereby deteriorate the condition of human life itself.

As moral agents we should experience a still greater alteration; of which more will be said under the next article.

Although, therefore, the Deity, who possesses the power of winding and turning, as he pleases, the course of causes which issue from himself, do in fact interpose to alter or intercept effects which, without such interposition, would have taken place; yet it is by no means incredible that his Providence, which always rests upon final good, may have made a *reserve* with respect to the manifestation of his interference, a part of the very plan which he has appointed for our terrestrial existence, and a part conformable with, or in some sort required by, other parts of the same plan. It is at any rate evident, that a large and ample province remains for the exercise of Providence without its being naturally perceptible by us; because obscurity, when applied to the interruption of laws, bears a necessary proportion to the imperfection of our knowledge when applied to the laws themselves, or rather to the effects which these laws, under their various and incalculable combinations, would of their own accord produce. And if it be said, that the doctrine of Divine Providence, by reason of the ambiguity under which its exertions present themselves, can be attended with no *practical* influence upon our conduct; that, although we believe ever so firmly that there is a Providence, we must prepare, and provide, and act, as if there were none; I answer, that this is admitted; and that we further allege, that so to prepare, and so to provide, is consistent with the most perfect assurance of the reality of a Providence: and not only so, but that it is, probably, one advantage of the present state of our information, that our provisions and preparations are not disturbed by it. Or if it be still asked, Of what use at all, then, is the doctrine, if it neither alter our measures nor regulate our conduct? I answer again, that it is of the greatest use, but that it is a doctrine of sentiment and piety, not (immediately at least) of action or conduct; that it applies to the consolation of men's minds, to their devotions, to the excitement of gratitude, the support of patience, the keeping alive and the strengthening of every motive for endeavouring to please our Maker; and that these are great uses.[*]

[*] The views taken in these three paragraphs are most important, and they lead to another of equal moment, (if, indeed, they do not include it,) respecting the obscurity which hangs over the subject of a Future State. Sceptics have constantly asked,—Why a matter, beyond all comparison the most important and the most interesting to man, should be left in any the least doubt? in other words, Why the combined operation of Natural and Revealed Religion should not be to make us just as certain of what shall befall us upon our removal from this world as we are of what is likely to happen on the morrow of any given day? The answer is,—*because* this matter is so immeasurably more important and more

OF ALL VIEWS under which human life has ever been considered, the most reasonable, in my judg

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interesting to us than all others; and *because*, unless our whole nature were changed, the absolute certainty of enjoyments without end and without limit would make the performance of our present task impossible. If indeed, the further question is pressed,—"Why are we so constituted?"—this is only another form of what in truth all these reasonings conceal, the question, Why man was created a finite being? For in this all the sceptical questions of the description adverted to invariably end. Thus, to take an instance from one gratification which of necessity presupposes evil,—There is pleasure in the cessation of pain, and in the enjoyment of rest after labour; as there also is in satisfying the thirst for knowledge. It is not a contingent but a necessary truth, that this gratification of ease, or of curiosity satisfied, cannot be obtained without the preceding evil of suffering or fatigue, or the preceding imperfection of ignorance. But it is said, why might we not have been so made as to have other equal pleasures without the evil? And had such been our constitution, the same objectors would have said,—"Here is one source of enjoyment cut off." Nay, if life were an alternation of positive enjoyment with mere ease, they would still say,—"Why any interval of positive enjoyment, compared with which mere ease is worthless, and so an evil?" And if all were positive enjoyment, they would say,—"Why is it not more exquisite?" In other words,—"Why is man a finite being?" All our ment, is that which regards it as a state of *probation*. If the course of the world was separated from the contrivances of nature, I do not know that it would be necessary to look for any other account of it than what, if it may be called an account, is contained in the answer, that events rise up by chance. But since the contrivances of nature decidedly evince *intention;* and since the course of the world and the contrivances of nature have the same author; we are, by the force of this connexion, led to believe that the appearance under which events take place, is reconcileable with the supposition of design on the part of the Deity. It is enough that they be reconcileable with this supposition; and it is undoubtedly

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speculations, however, upon this subject must proceed upon the assumption that the design of Providence was to create a finite, mortal creature, endowed with free will, but influenced by motives inducing and dissuading. Any inquiry into the reason for such a determination being taken by the Supreme Being far exceeds the bounds of our faculties; and the question as to evil must be always handled with the impression that, beyond a certain way, we never can make progress towards its entire solution. The whole subject, with the different doctrines held upon it, will be treated at large in the Appendix, where it will be contended that the most enlarged views lead to the conclusion of rational optimism and a probationary state.

true that they may be reconcileable, though we cannot reconcile them. The mind, however, which contemplates the works of nature, and in those works sees so much of means directed to ends, of beneficial effects brought about by wise expedients, of concerted trains of causes terminating in the happiest results; so much, in a word, of counsel, intention, and benevolence; a mind, I say, drawn into the habit of thought which these observations excite, can hardly turn its view to the condition of our own species without endeavouring to suggest to itself some purpose, some design, for which the state in which we are placed is fitted, and which it is made to serve. Now we assert the most probable supposition to be, that it is a state of moral probation; and that many things in it suit with this hypothesis which suit no other. It is not a state of unmixed happiness, or of happiness simply; it is not a state of designed misery, or of misery simply: it is not a state of retribution; it is not a state of punishment. It suits with none of these suppositions. It accords much better with the idea of its being a condition calculated for the production, exercise, and improvement of moral qualities, with a view to a future state, in which these qualities, after being so produced, exercised, and improved, may, by a new and more favourable constitution of things, receive their reward, or become their own. If it be said, that this is to enter upon a religious rather than a philosophical consideration, I answer, that the name of Religion ought to form no objection if it shall turn out to be the case that the more religious our views are the more probability they contain. The degree of beneficence, of benevolent intention, and of power, exercised in the construction of sensitive beings, goes strongly in favour, not only of a creative, but of a continuing care, that is, of a ruling Providence. The degree of chance which appears to prevail in the world requires to be reconciled with this hypothesis. Now it is one thing to maintain the doctrine of Providence along with that of a future state, and another thing without it. In my opinion, the two doctrines must stand or fall together. For although more of this apparent chance may perhaps, upon other principles, be accounted for than is generally supposed, yet a future state alone rectifies all disorders: and if it can be shown that the appearance of disorder is consistent with the uses of life as a *preparatory* state, or that in some respects it promotes these uses, then, so far as this hypothesis may be accepted, the ground of the difficulty is done away.

In the wide scale of human condition there is not perhaps one of its manifold diversities which does not bear upon the design here suggested. Virtue is infinitely various. There is no situation in which a rational being is placed, from that of the best-instructed Christian down to the condition of the rudest barbarian, which affords not room for moral agency; for the acquisition, exercise, and display of voluntary qualities, good and bad. Health and sickness, enjoyment and suffering, riches and poverty, knowledge and ignorance, power and subjection, liberty and bondage, civilization and barbarity, have all their offices and duties, all serve for the *formation* of character: for when we speak of a state of trial, it must be remembered that characters are not only tried, or proved, or detected, but that they are generated also, and *formed*, by circumstances. The best dispositions may subsist under the most depressed, the most afflicted fortunes. A West-Indian slave, who amidst his wrongs, retains his benevolence, I, for my part, look upon as amongst the foremost of human candidates for the rewards of virtue. The kind master of such a slave, that is, he who, in the exercise of an inordinate authority, postpones, in any degree, his own interest to his slave's comfort, is likewise a meritorious character; but still he is inferior to his slave. All however which I contend for is, that these destinies, opposite as they may be in every other view, are both *trials;* and equally such. The observation may be applied to every other condition: to the whole range of the scale, not excepting even its lowest extremity. *Savages* appear to us all alike; but it is owing to the distance at which we view savage life, that we perceive in it no discrimination of character. I make no doubt but that moral qualities, both good and bad, are called into action as much, and that they subsist in as great variety in these inartificial societies as they are or do in polished life. Certain at least it is, that the good and ill treatment which each individual meets with depends more upon the choice and voluntary conduct of those about him than it does or ought to do under regular civil institutions and the coercion of public laws. So again, to turn our eyes to the other end of the scale, namely, that part of it which is occupied by mankind enjoying the benefits of learning, together with the lights of revelation; there also the advantage is all along *probationary.* Christianity itself, I mean the revelation of Christianity, is not only a blessing but a trial. It is one of the diversified means by which the character is exercised: and they who require of Christianity that the revelation of it should be universal may possibly be found to require that one species of probation should be adopted, if not to the exclusion of others, at least to the narrowing of that variety which the wisdom of the Deity hath appointed to this part of his moral œconomy.*

Now if this supposition be well founded; that is, if it be true that our ultimate or our most permanent happiness will depend, not upon the temporary condition into which we are cast, but upon our behaviour in it; then is it a much more fit subject of *chance* than we usually allow or apprehend it to be, in what manner the variety of external circumstances which subsist in the human world is distributed amongst the individuals of the species. "This life being a state of probation, it is immaterial," says Rousseau, "what kind of trials we experience in it, provided they produce their effects." Of two agents who stand indifferent to the moral Governor of the universe, one may be exercised by riches, the other by poverty. The treatment of these two shall appear

* The reader will observe that I speak of the revelation of Christianity as distinct from Christianity itself. The *dispensation* may already be universal. That part of mankind which never heard of CHRIST'S name, may nevertheless be redeemed, that is, be placed in a better condition, with respect to their future state, by his intervention; may be the objects of his benignity and intercession, as well as of the propitiatory virtue of his passion. But this is not "natural theology;" therefore I will not dwell longer upon it.—*Note of the Author.*

to be very opposite, whilst in truth it is the same; for though, in many respects, there be great disparity between the conditions assigned, in one main article there may be none, *viz.* in that they are alike trials; have both their duties and temptations, not less arduous or less dangerous in one case than the other; so that if the final award follow the character, the original distribution of the circumstances under which that character is formed, may be defended upon principles not only of justice but of equality. What hinders, therefore, but that mankind may draw lots for their condition? They take their portion of faculties and opportunities, as any unknown cause, or concourse of causes, or as causes acting for other purposes, may happen to set them out: but the event is governed by that which depends upon themselves, the application of what they have received. In dividing the talents, no rule was observed: none was necessary: in rewarding the use of them, that of the most correct justice. The chief difference at last appears to be, that the right use of more talents, *i. e.* of a greater trust, will be more highly rewarded than the right use of fewer talents, *i. e.* of a less trust. And since, for other purposes, it is expedient that there be an inequality of concredited talents here, as well probably as an inequality of conditions hereafter, though all remuneratory,—can any rule, adapted to that inequality, be more agreeable, even to our apprehensions of distributive justice, than this is?

We have said that the appearance of *casualty* which attends the occurrences and events of life not only does not interfere with its uses, as a state of probation, but that it promotes these uses.

Passive virtues, of all others the severest and the most sublime; of all others, perhaps, the most acceptable to the Deity,—would, it is evident, be excluded from a constitution in which happiness and misery regularly followed virtue and vice. Patience and composure under distress, affliction, and pain; a steadfast keeping up of our confidence in God, and of our reliance upon his final goodness, at the time when every thing present is adverse and discouraging; and (what is no less difficult to retain) a cordial desire for the happiness of others, even when we are deprived of our own; these dispositions, which constitute, perhaps, the perfection of our moral nature, would not have found their proper office and object in a state of avowed retribution; and in which, consequently, endurance of evil would be only submission to punishment.

Again: one man's sufferings may be another man's trial. The family of a sick parent is a school of filial piety. The charities of domestic life, and not only these, but all the social virtues, are called out by distress. But then misery, to be the proper object of mitigation, or of that benevolence which endeavours to relieve, must be really or apparently casual. It is upon such sufferings alone that benevolence can operate. For were there no evils in the world but what were punishments, properly and intelligibly such, benevolence would only stand in the way of justice. Such evils, consistently with the administration of moral government, could not be prevented or alleviated, that is to say, could not be remitted in whole or in part, except by the authority which inflicted them, or by an appellate or superior authority. This consideration, which is founded in our most acknowledged apprehensions of the nature of penal justice, may possess its weight in the Divine counsels. Virtue perhaps is the greatest of all ends. In human beings, relative virtues form a large part of the whole. Now relative virtue presupposes, not only the existence of evil, without which it could have no object, no material to work upon, but that evils be apparently, at least, *misfortunes*; that is, the effects of apparent chance. It may be in pursuance, therefore, and in furtherance of the same scheme of probation, that the evils of life are made so to present themselves.

I have already observed, that when we let in religious considerations we often let in light upon the difficulties of nature. So in the fact now to be accounted for, the *degree* of happiness which we usually enjoy in this life may be better suited to a state of trial and probation than a greater degree would be. The truth is, we are rather too much delighted with the world than too little. Imperfect, broken, and precarious as our pleasures are, they are more than sufficient to attach us to the eager pursuit of them. A regard to a *future* state can hardly keep its place as it is. If we were designed therefore to be influenced by that regard, might not a more indulgent system, a higher or more uninterrupted state of gratification, have interfered with the design? At least it seems expedient that mankind should be susceptible of this influence, when presented to them; that the condition of the world should not be such as to exclude its operation, or even to weaken it more than it does. In a religious view (however we may complain of them in every other), privation, disappointment, and satiety are not without the most salutary tendencies.

CHAPTER XXVII.

CONCLUSION.

In all cases, wherein the mind feels itself in danger of being confounded by variety, it is sure to rest upon a few strong points, or perhaps upon a single instance. Amongst a multitude of proofs, it is *one* that does the business. If we observe in any argument, that hardly two minds fix upon the same instance, the diversity of choice shows the strength of the argument, because it shows the number and competition of the examples. There is no subject in which the tendency to dwell upon select or single topics is so usual, because there is no subject, of which, in its full extent, the latitude is so great, as that of natural history applied to the proof of an intelligent Creator. For my part, I take my stand in human anatomy; and the examples of mechanism I should be apt to draw out from the copious catalogue which it supplies, are the pivot upon which the head turns, the ligaments within the socket of the hip-joint, the pulley or trochlear muscles of the eye, the epiglottis, the bandages which tie down the tendons of the wrist and instep, the slit or perforated muscles at the hands and feet, the knitting of the intestines to the mesentery, the course of the chyle into the blood, and the constitution of the sexes as extended throughout the whole of the animal creation. To these instances, the reader's memory will go back, as they are severally set forth in their places: there is not one of the number which I do not think decisive; not one which is not strictly mechanical: nor have I read or heard of any solution of these appearances, which, in the smallest degree, shakes the conclusion that we build upon them.

But, of the greatest part of those, who, either in this book or any other, read arguments to prove the existence of a God, it will be said, that they leave off only where they began; that they were never ignorant of this great truth, never doubted of it; that it does not therefore appear, what is gained by researches from which no new opinion is learned, and upon the subject of which no proofs were wanted. Now I answer that, by *investigation*, the following points are always gained, in favour of doctrines even the most generally acknowledged (supposing them to be true), *viz.* stability and impression. Occasions will arise to try the firmness of our most habitual opinions. And upon these occasions, it is a matter of incalculable use to feel our foundation find a support in argument for what we had taken up upon authority. In the present case, the arguments upon which the conclusion rests are exactly such, as a truth of universal concern ought to rest upon. "They are sufficiently open to the views and capacities of the unlearned, at the same time that they acquire new strength and lustre from the discoveries of the learned." If they had been altogether abstruse and recondite, they would not have found their way to the understandings of the mass of mankind; if they had been merely popular, they might have wanted solidity.

But, secondly, what is gained by research in the stability of our conclusion, is also gained from it in *impression*.[39] Physicians tell us, that there

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[39] We have adverted in a former note (Chap. xxv.) to the lamented silence of Laplace upon the inferences to which his most important researches so naturally lead. An objection of a kind in some respects similar, but in others materially different, has often been urged against another class of writers,—the historians who record, without observation, events in which pious men are prone to trace the interposition of Providence. This charge was brought, upon one remarkable occasion, against the narrative of a celebrated voyage of discovery; and the author, Dr. Hawkesworth, defended himself in an elaborate and ingenious manner: He urged that either the event (the ceasing of the wind at a critical moment, by

is a great deal of difference between taking a medicine, and the medicine getting into the constitution. A difference not unlike which obtains with respect to those great moral propositions,

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which Captain Cook's ship, after it had struck on a coral rock, was saved, contrary to all expectation) happened in the ordinary course of nature, and then ought no more to be called providential than the rising of the sun upon any given day; or it was produced by an extraordinary interposition, and then the same power might have rendered this unnecessary by preventing the ship from striking. (Voyages, vol. i. p. xxi., second edition.) But this reasoning proceeds upon an entire misapprehension of the objection. No one denies that the good and the evil come from the same Almighty hand; but resting in the belief, avowed by Dr. Hawkesworth himself in explicit terms, that "the Supreme Being is equally wise and benevolent in the dispensation of both evil and good as means of effecting ultimate purposes worthy of his ineffable perfections," (*ib.* p. xx.) we may, with the most absolute consistency, express thankfulness for the one and resigned submission to the other dispensation; and it is a wholesome habit of thinking, and one according with our duty to that awful and benevolent Being, as well as conducive to our own mental improvement, to make our gratitude for his bounties keep pace with our resignation to his will. Those, therefore, who, like Laplace, pass by an occasion of marking the proofs of his existence and intelligence where it naturally presents itself, expose which ought to form the directing principles of human conduct. It is one thing to assent to a proposition of this sort; another, and a very different thing, to have properly imbibed its influence. I take the case to be this: perhaps almost every man living has a particular train of thought, into which his mind glides and falls, when at leisure from the impressions and ideas that occasionally excite it: perhaps, also, the train of thought, here spoken of, more than any other thing, determines the character. It is of the utmost consequence, therefore, that this property of our constitution be well regulated. Now it is by frequent or continued meditation upon a subject, by placing a subject in different points of view, by induction of particulars, by variety of examples, by applying principles to the solution of phænomena, by dwelling upon proofs and consequences, that mental exercise is drawn into any particular channel. It it by these means, at least, that we have any power over it. The train of spontaneous thought, and the choice of that train, may be directed to different ends, and may ap-

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themselves to blame; and those who, as it were, go out of their way to avoid marking instances of his bounty, are alike censurable. Both classes neglect a fit opportunity of promoting human improvement.

pear to be more or less judiciously fixed, according to the purpose in respect of which we consider it: but, in a *moral view*, I shall not, I believe, be contradicted when I say, that, if one train of thinking be more desirable than another, it is that which regards the phænomena of nature with a constant reference to a supreme intelligent Author. To have made this the ruling, the habitual sentiment of our minds, is to have laid the foundation of every thing which is religious. The world thenceforth becomes a temple, and life itself one continued act of adoration. The change is no less than this; that, whereas formerly God was seldom in our thoughts, we can now scarcely look upon any thing without perceiving its relation to him. Every organised natural body, in the provisions which it contains for its sustentation and propagation, testifies a care, on the part of the Creator, expressly directed to these purposes. We are on all sides surrounded by such bodies; examined in their parts, wonderfully curious; compared with one another, no less wonderfully diversified. So that the mind, as well as the eye, may either expatiate in variety and multitude, or fix itself down to the investigation of particular divisions of the science. And in either case it will rise up from its occupation, possessed by the subject, in a very different manner, and with a very different degree of influence, from what a mere assent to any verbal proposition which can be formed concerning the existence of the Deity, at least that merely complying assent with which those about us are satisfied, and with which we are too apt to satisfy ourselves, will or can produce upon the thoughts. More especially may this difference be perceived, in the degree of admiration and of awe, with which the Divinity is regarded, when represented to the understanding by its own remarks, its own reflections, and its own reasonings, compared with what is excited by any language that can be used by others. The works of nature want only to be contemplated. When contemplated they have every thing in them which can astonish by their greatness: for, of the vast scale of operation through which our discoveries carry us, at one end we see an intelligent Power arranging planetary systems, fixing, for instance, the trajectory of *Saturn,* or constructing a ring of two hundred thousand miles diameter, to surround his body, and be suspended like a magnificent arch over the heads of his inhabitants; and, at the other, bending a hooked tooth, concerting and providing an appropriate mechanism, for the clasping and reclasping of the filaments of the feather of the humming-bird. We have proof, not only of both these works proceeding from an intelligent agent, but of their proceeding from the same agent: for, in the first place, we can trace an identity of plan, a connexion of system, from Saturn to our own globe; and when arrived upon our globe, we can, in the second place, pursue the connexion through all the organised, especially the animated, bodies which it supports. We can observe marks of a common relation, as well to one another, as to the elements of which their habitation is composed. Therefore one mind hath planned, or at least hath prescribed, a general plan for all these productions. One Being has been concerned in all.

Under this stupendous Being we live. Our happiness, our existence, is in his hands. All we expect must come from him. Nor ought we to feel our situation insecure. In every nature, and in every portion of nature, which we can descry, we find attention bestowed upon even the minutest parts. The hinges in the wings of an *earwig*, and the joints of its antennæ, are as highly wrought, as if the Creator had had nothing else to finish. We see no signs of diminution of care by multiplicity of objects, or of distraction of thought by variety. We have no reason to fear, therefore, our being forgotten, or overlooked, or neglected."

" There is assuredly nothing that more tends to absorb

The existence and character of the Deity is, in every view, the most interesting of all human speculations. In none, however, is it more so, than as it facilitates the belief of the fundamental articles of *Revelation*. It is a step to have it proved, that there must be something in the world more than what we see. It is a farther step to know, that, amongst the invisible things of nature, there must be an intelligent mind, concerned in its production, order, and support. These points being assured to us by Natural Theology, we may well leave to Revelation the disclosure of many particulars, which our researches cannot reach, respecting either the nature of this Being as the original cause of all

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our whole faculties in devout admiration than the contemplation of that universal power and pervading skill which is here remarked by the author. The same being that fashioned the insect whose existence is only discerned by a microscope, and gave that invisible speck a system of ducts and other organs to perform its vital functions, created the enormous mass of the planet thirteen hundred times larger than our earth, and launched it in its course round the sun,—and the comet, wheeling with a velocity that would carry it round our globe in less than two minutes of time, and yet revolving through so prodigious a space that it takes near six centuries to encircle the sun!

things, or his character and designs as a moral governor; and not only so, but the more full confirmation of other particulars, of which, though they do not lie altogether beyond our reasonings and our probabilities, the certainty is by no means equal to the importance. The true theist will be the first to listen to *any* credible communication of Divine knowledge. Nothing which he has learnt from Natural Theology will diminish his desire of further instruction, or his disposition to receive it with humility and thankfulness. He wishes for light: he rejoices in light. His inward veneration of this great Being will incline him to attend with the utmost seriousness, not only to all that can be discovered concerning him by researches into nature, but to all that is taught by a revelation which gives reasonable proof of having proceeded from him.

But, above every other article of revealed religion, does the anterior belief of a Deity bear with the strongest force upon that grand point, which gives indeed interest and importance to all the rest,—the resurrection of the human dead. The thing might appear hopeless, did we not see a power at work adequate to the effect, a power under the guidance of an intelligent will, and a power penetrating the inmost recesses of all substance. I am far from justifying the opinion of those who "thought it a thing incredible that God should raise the dead:" but I admit that it is first necessary to be persuaded, that there *is* a God to do so. This being thoroughly settled in our minds, there seems to be nothing in this process (concealed as we confess it to be) which need to shock our belief. They who have taken up the opinion that the acts of the human mind depend upon *organisation*, that the mind itself indeed consists in organisation, are supposed to find a greater difficulty than others do in admitting a transition by death to a new state of sentient existence, because the old organisation is apparently dissolved. But I do not see that any impracticability need be apprehended even by these; or that the change, even upon their hypothesis, is far removed from the analogy of some other operations which we know with certainty that the Deity is carrying on. In the ordinary derivation of plants and animals from one another, a particle, in many cases, minuter than all assignable, all conceivable dimension,—an aura, an effluvium, an infinitesimal,—determines the organisation of a future body: does no less than fix, whether that which is about to be produced shall be a vegetable, a merely sentient, or a rational being; an oak, a frog, or a philosopher; makes all these differences; gives to the future body its qualities, and nature, and species. And this particle, from which springs, and by which is determined, a whole future nature, itself proceeds from, and owes its constitution to, a prior body: nevertheless, which is seen in plants most decisively, the incepted organisation, though formed within, and through, and by, a preceding organisation, is not corrupted by its corruption, or destroyed by its dissolution: but, on the contrary, is sometimes extricated and developed by those very causes; survives and comes into action, when the purpose for which it was prepared requires its use. Now an economy which nature has adopted, when the purpose was to transfer an organisation from one individual to another, may have something analogous to it when the purpose is to transmit an organisation from one state of being to another state: and they who found thought in organisation may see something in this analogy applicable to their difficulties; for, whatever can transmit a similarity of organisation will answer their purpose, because, according even to their own theory, it may be the vehicle of consciousness, and because consciousness carries identity and individuality along with it through all changes of form or of visible qualities. In the most general case, that, as we have said, of the derivation of plants and animals from one another, the latent organisation is either itself similar to the old organisation, or has the power of communicating to new matter the old organic form. But it is not restricted to this rule. There are other cases, especially in the progress of insect life, in which the dormant organisation does not much resemble that which encloses it, and still less suits with the situation in which the enclosing body is placed, but suits with a different situation to which it is destined. In the larva of the libellula, which lives constantly, and has still long to live under water, are descried the wings of a fly, which two years afterwards is to mount into the air. Is there nothing in this analogy? It serves at least to show, that, even in the observable course of nature, organisations are formed one beneath another; and, amongst a thousand other instances, it shows completely that the Deity can mould and fashion the parts of material nature, so as to fulfil any purpose whatever which he is pleased to appoint.

They who refer the operations of mind to a substance totally and essentially different from matter (as most certainly these operations, though affected by material causes, hold very little affinity to any properties of matter with which we are acquainted), adopt perhaps a juster reasoning and a better philosophy: and by these the considerations above suggested are not wanted, at least in the same degree. But to such as find, which some persons do find, an insuperable difficulty in shaking off an adherence to those analogies, which the corporeal world is continually suggesting to their thoughts; to such I say, every consideration will be a relief, which manifests the extent of that intelligent power which is acting in nature, the fruitfulness of its resources, the variety, and aptness, and success of its means; most especially every consideration, which tends to show that, in the translation of a conscious existence, there is not, even in their own way of regarding it, any thing greatly beyond, or totally unlike, what takes place in such parts (probably small parts) of the order of nature, as are accessible to our observation.

Again: if there be those who think, that the contractedness and debility of the human faculties in our present state seem ill to accord with the high destinies which the expectations of religion point out to us; I would only ask them, whether any one, who saw a child two hours after its birth, could suppose that it would ever come to understand *fluxions*;* or who then shall say, what further amplification of intellectual powers, what accession of knowledge, what ad-

* See Search's Light of Nature, *passim.*

vance and improvement, the rational faculty, be its constitution what it will, may not admit of, when placed amidst new objects, and endowed with a sensorium adapted, as it undoubtedly will be, and as our present senses are, to the perception of those substances, and of those properties of things, with which our concern may lie.

Upon the whole; in every thing which respects this awful, but, as we trust, glorious change, we have a wise and powerful Being (the author, in nature, of infinitely various expedients for infinitely various ends), upon whom to rely for the choice and appointment of means adequate to the execution of any plan which his goodness or his justice may have formed, for the moral and accountable part of his terrestrial creation. That great office rests with *him;* be it *ours* to hope and to prepare, under a firm and settled persuasion, that, living and dying, we are his; that life is passed in his constant presence, that death resigns us to his merciful disposal.

APPENDIX:

CONTAINING ADDITIONAL

NOTES AND ILLUSTRATIONS

TO

PALEY'S

NATURAL THEOLOGY,

BY

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

FORMERLY PROF. ROY. COLL. SURG., AND MEM. COUNCIL OF LONDON,
AND NOW OF THE UNIVERSITY OF EDINBURGH.

I.

ON CHAPTERS I. AND II., AND INTRODUCTORY TO THE MECHANISM OF THE FRAME.

ARCHDEACON PALEY has, in these two introductory chapters, given us the advantage of simple, but forcible language, with extreme ingenuity, in illustration. But for his example, we should have felt some hesitation in making so close a comparison between design, as exhibited by the Creator in the animal structure, and the mere mechanism, the operose and imperfect contrivances of human art.

Certainly, there may be a comparison; for a superficial and rapid survey of the animal body may convey the notion of an apparatus of levers, pullies, and ropes—which may be compared with the spring, barrel, and fusee, the wheels and pinions, of a watch. But if we study the texture of animal bodies more curiously, and especially if we compare animals with each other—for example, the simple structure of the lower creatures with the complicated structure of those higher in the scale of existence—we shall see, that in the lowest links of the chain animals are so simple, that we should almost call them homogeneous; and yet in these we find life, sensibility, and motion. It is in the animals higher in the scale that we discover parts having distinct endowments, and exhibiting complex mechanical relations. The mechanical contrivances which are so obvious in man, for instance, are the provisions for the agency and dominion of an intellectual power over the materials around him.

We mark this early, because there are authors who, looking upon this complexity of mechanism, confound it with the presence of life itself, and think it a necessary adjunct—nay, even that life proceeds from it: whereas the mechanism which we have to examine in the animal body is formed with reference to the necessity of acting upon, or receiving impressions from, things external to the body—a necessary condition of our state of existence in a material world.

Many have expressed their opinion very boldly on the necessary relation between organisation and life, who have never extended their views to the system of nature. To place man, an intelligent and active being, in this world of matter, he must have properties bearing relation to that matter. The existence of matter implies an agency of certain forces;—the particles of bodies must suffer attraction and repulsion; and the bodies formed by the balance of these influences upon their atoms or particles must have weight or gravity, and possess mechanical properties. So must the living body, independently of its peculiar endowments, have similar composition and qualities, and have certain relations to the solids, fluids, gases, heat, light, electricity, or galvanism, which are around it. Without these, the intellectual principle could receive no impulse—could have no agency and no relation to the material world. The whole body must gravitate or have weight; without which it could neither stand securely, nor exert its powers on the bodies around it. But for this, muscular power itself, and all the appliances which are related to that power, would be useless. When, therefore, it is affirmed that organisation or construction is necessary to life, we may at least pause in giving assent, under the certainty that we see another and a different reason for the construction of the body. Thus we perceive, that as the body must have weight to have power, so must it have mechanical contrivance, or arrangement of its parts. As it must have weight, so must it be sustained by a skeleton; and when we examine the bones, which give the body height and shape, we find each column (for in that sense a bone may be first taken) adjusted with the finest attention to the perpendicular weight that it has to bear, as well as to the lateral thrusts to which it is subject in the motions of the body.

The bones also are as levers, on the most accurate mechanical principles. And whilst these bones are necessary to give firmness and strength to the frame, it is admirable to observe, that one bone never touches another; but a fine elastic material, the cartilage, intervenes betwixt their ends, the effect of which is to give a very considerable degree of elasticity to the whole frame. Without such elasticity, a jar would reach the more delicate organs, even in the very recesses of the body, at every violent motion; and, but for this provision, every joint would creak by the attrition of the surfaces of the bones. The bones are surrounded with the flesh or muscles. The muscle is a particular fibrous texture, which alone, of all the materials constituting the frame, possesses the peculiar inherent power or endowment of contracting: it is this power which we are to understand, when professional men speak of irritability. The contraction of the muscle bears no proportion to the cause which brings it into operation, more than the touch of the spur upon the horse's side does as a mechanical impetus to the force with which the animal propels both himself and rider. Each muscle of the body—and by common estimate there are hundreds—is isolated; and no property of motion is propagated from one to another; they are distinct instruments of motion. The muscles surround the bones, and are so beautifully classed, that in every familiar motion of the limbs some hundreds of them are adjusted in their exact degree, to effect the simplest change in the position of the body.

Each fibre of a muscle, and a muscle may contain millions of fibres, is so attached to the tendon, that the whole power is concentrated there; and it is the tendons of the muscles which, like ropes, convey the force of the muscles to the bones. The bones are passive levers; the muscles are the active parts of the frame.

With all the seeming intricacy in the running and crossing of these tendons, they are adjusted accurately on mechanical principles. Where it is necessary, they run in sheaths, or they receive new directions by lateral ligamentous attachments, or there are placed under them smooth and lubricated pullies, over which they run; and where there is much friction, there is a provision equal in effect to the friction-wheel of machinery.

Thus the bones are levers, with their heads most curiously carved and articulated; and, joined to the intricate relations of the muscles and tendons, they present on the whole a piece of perfect mechanism.

It is with this texture—the coarsest, roughest portion of the animal frame—that our author is running a parallel when he compares it with the common mechanical contrivances of machinery.

Whilst these grosser parts of the animal body exhibit a perfection in mechanical adaptation far greater than the utmost ingenuity of man can exhibit in his machinery, let the reader remember that they bear no comparison with the finer parts of the animal body: such, for example, as the structure of those nerves which convey the mandate of the will to the moving parts, or of the vessels which are conveying the blood in the circulation, and where the laws of hydraulics may be finely illustrated; or of those secreting glands where some will affirm the galvanic influence is in operation with something finer than the apparatus of plates and troughs.

But were we to institute a comparison between the mechanical contrivances of man and these finer mechanisms in the animal frame, we must recollect that there are structures in the body much more admirable, as we shall have abundant opportunities of showing as we proceed in the present volume. The organs of the senses, which are so many inlets for the qualities of surrounding matter to excite corresponding sensations and perceptions, will afford us delightful subjects of contemplation; and proofs more conclusive of design in the human body—not only in regard to the system of that body itself, but as it forms a part of the system of the universe.

II.

ON DESIGN AS EXHIBITED IN THE MECHANICAL STRUCTURE OF ANIMAL BODIES.

In all animal bodies, besides those structures on which their economy and much of their vital functions depend, there is a firm texture necessary. Without this, the vegetable would have no characteristic form; and animals would want the protection necessary for their delicate organs, and could not move upon their extremities. We have to show with what admirable contrivance, in the different classes of organized beings, this firm fabric is reared—sometimes to protect the parts, as a shell, and sometimes to give them form and motion, as in the skeleton.

In vegetables, as in animals, there is a certain firm material necessary to support the parts which are the living active organs of their system, and which are so beautiful and interesting. The ligneous or woody fibre is a minute, elastic, semi-opaque filament, which, closing in and adhering to other filaments of the same kind, forms the grain or solid part of the wood. The best demonstration of the office of the woody fibre is in the leaf. When the leaf of a plant is prepared by maceration and putrefaction, and the soft part washed away, there remains an elegant skeleton of wood, which retains the form of the leaf, and which is perfectly well suited to support its delicate organization. It is the same substance which, when accumulated and condensed, gives form and strength to the roots and branches of the oak; and these, though fantastic and irregular in their growth, preserve a mechanical principle of strength as obvious to the ship-builder, in the knees of timber, as in the delicate skeleton of the leaf. Lord Bacon speaks of "knee-timber, that is good for ships that are to be tossed." The woody fibre, though not directly engaged in the living functions of the tree, is yet essential for extending the branches and leaves to the influence of the atmosphere, and by its elasticity under the pressure of the wind, giving what is equivalent to exercise for the motion of the sap. A tree opposed to winds and to a severe climate is dense in its grain, and the wood is preferred by the workman to that which is the growth of a milder climate.

We cannot miss seeing the analogy of the woody fibre with the bones of animals. Bones are firm, to sustain the animal's weight, and to give it form. They are jointed, and move under the action of muscles; and this exercise promotes the activity of the living parts, and is necessary to health. But let us first observe the structure of some of the lower animals. It will be agreeable to find the hard material, though always appropriate and perfect, becoming more and more mechanical and complex in its construction, from the lithophytes, testacea, crustacea, reptiles, fishes, mammalia, up to man.

The texture of a sponge, its form and elasticity, depend upon a membranous and horny substance, to which both siliceous and calcareous spiculæ are added.

Carbonate of lime is the hardening material of shell, united to a membranous or cartilaginous animal matter. Our author describes the slime of a snail hardening into shell by the influence of the atmosphere; but this is a very imperfect, and indeed erroneous view of the matter. The shell of the oyster, and even the pearl, consist of concentric layers of membrane and carbonate of lime; and it is their lamellated arrangement which causes the beautiful iridescence in the polished surface of those shells*. In the rough outer surface of an oyster-shell, we shall see the marks of the successive layers. We have to understand, that that which now forms the centre and utmost convexity of the shell was, at an earlier

* See the discoveries of Sir David Brewster on this subject. Phil. Trans. 1814, p. 397.

stage, sufficient to cover the whole animal. But as the oyster grows, it throws out from its surface a new secretion, composed of animal matter and carbonate of lime, which is attached to the shell already formed, and projects farther at its edges. Thus the animal is not only protected by this covering, but, as it grows, the shell is made thicker and stronger by successive layers.

The reader will not be unwilling that we should stop here to show that, rudely composed as this covering of the oyster seems to be, it not only answers the purpose of protecting the animal, but is shaped with as curious a destination to the vital functions of respiration and obtaining food as anything we can survey in the higher animals. We cannot walk the streets without noticing that, in the fish-shops, the oysters are laid with their flat sides uppermost; they would die were it otherwise. The animal breathes and feeds by opening its shell, and thereby receiving a new portion of water into the concavity of its under-shell; and if it did not thus open it shell, the water could neither be propelled through its bronchiæ or respiratory apparatus, nor sifted for its food. It is in this manner that they lie in their native beds: were they on their flat surface, no food could be gathered, as it were, in their cup; and if exposed by the retreating tide, the opening of the shell would allow the water to escape, and leave them dry—thus depriving them of respiration as well as food*.

We perceive, then, that the form of the oyster-shell, rude as it seems, is not a thing of chance. Since the shell is a cast of the body of the animal, the peculiar shape must have been given to the soft parts, in anticipation of that of the shell—an instance of prospective contrivance.

That the general conformation of the shell should have relation to what we may term its function, will be less surprising when we find a minute mechanical intention in each layer of that shell. We should be inclined to say that the earthy matter of the shell crystallizes, were it not that the striated or fibrous appearance differs in the direction of the fibres in each successive stratum—each layer having the striæ composing it parallel to one another, but directed obliquely to those of the layer previously formed, and the whole exhibiting a strong texture arranged upon well-known mechanical principles.

Shell is not alive, as true bone is. If the shell of any of the testacea be broken, the surface of the animal secretes a new shell; not, however, by the

* In confirmation of these remarks, the geologist, when he sees those shells in beds of diluvium, can determine whether the oysters were overwhelmed in their native beds, or were rolled away and scattered as shells merely.

concretion of mucus, but by the regular secretion of a substance combined of earthy and gelatinous matter*. Delicate experiments have been made by steeping shells in diluted nitric acid, by which it is shown that the carbonate of lime is the earthy material of shells; and that, when that earth is dissolved in the acid, a gelatinous substance of the form of the shell remains.

Crustaceous animals, such as the lobster and crab,† have their shell formed of the same substances as the testacea, but with the addition of phosphate of lime to the carbonate of lime. A question may arise, How do these animals grow? It is said that they cast their shells and remain retired until a new shell is secreted; and Réaumur has given a very particular account of the process of separation in the cray-fish. Naturalists have not found these cast-off shells. If they be not cast, the animals must, at a particular season, have their shells so softened as to permit sudden expansion of their bodies within; yet it would be difficult to say by what internal means this shell could be thus softened and made pliant. We presume the reason that the shells of the crustacea are not found in our museums is because they are

* We owe our knowledge of the formation of shell to the great French naturalist Réaumur, who, by ingenious experiments, showed the distinction of shell and bone, and that the former was secreted from the surface of the animal.

† Vol. i. p. 346.

not thrown off at once, but that the portions are detached in succession. In these crustacea we find an approximation to bone, inasmuch as the shell is articulated, and has certain processes directed inwards to which the muscles are attached.

The hardening material of bone is the phosphate of lime; and this earthy substance is not merely united with cartilage or gelatinous matter, but membranes and vessels enter into the composition of bone. Bone is not excreted, or thrown out of the system of the animal body, but, on the contrary, it participates in those laws that govern living matter. It is continually undergoing the changes of deposition and absorption, under the influence of blood-vessels and absorbing vessels; by which means it grows with the growth of the soft parts.

In fishes, which live in an element that supports the weight, the bones have a very large proportion of elastic cartilage in their composition, and some have so little of the phosphate of lime in their bones as to be denominated cartilaginous fishes. Indeed, in the higher classes of animals which live upon land, there is in the different bones a finely-appropriated union of earth, cartilage, and fibre, to give them the due proportion of resistance, elasticity, and toughness. Not only is the bone of each class of animal peculiar in the proportion of the ingredients, but each bone of the skeleton, as of man, has a due proportion of earth, and cartilage, and fibre to suit its office. The temporal bone, in which the ear is situated, is as dense as marble (it is called *os petrosum*), and of course is suited to propagate the vibration of sound: the heel-bone, or the projection of the elbow, on which the powerful muscles pull, is, on the other hand, fibrous, as if partaking of the nature of a tendon or rope; whilst the columnar bones, which support the weight, have an intermediate degree of density, and an admirable form, as we shall see presently.

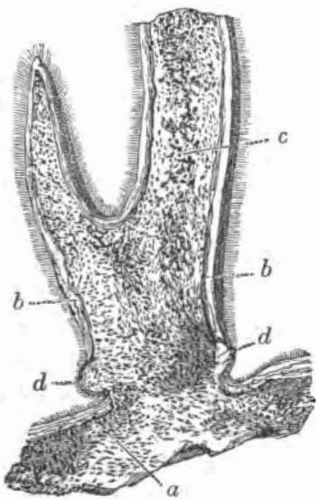
Let us consider the structure, growth, and decay of the deer's horns, as an example of the most rapid growth of bone, and a curious instance of its appropriation to a particular purpose. And, first, why should these antlers be deciduous, falling at an appointed season? The breeder of domestic cattle and horses endeavours to propagate the favourite qualities of fleece or carcase, of speed or power, by crossing. Nature accomplishes her purpose by giving to the strongest.

The antlers of the stag which is in maturity and vigorous health grow with the greatest spread of palms and crotches: with the growth of the horn there is increase of strength in the neck and shoulder*. We cannot be surprised, then, that

* The carotid artery, which nourishes the head, increases rapidly in size during the growth of the antlers.

in contention with his rivals, he that carries the largest antlers should obtain supremacy over the herd. After the season, his antlers fall; and we then find the stag feeding with the other males, which before he had driven off. Be this, however, as it may, the growth and fall of the horn is a remarkable phenomenon, and deserving further consideration.

The horn of the deer is bone, and is formed as an internal part, that is to say, it is covered during its growth. It grows from the outer table of the skull, *a*; but there extends, at the same time, from the integuments of the head, a soft vascular



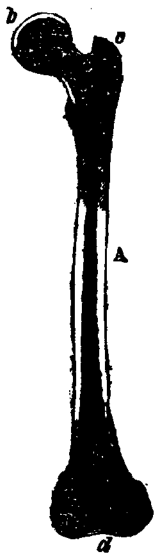
Section of the root of a deer's horn.

covering, *b*, like velvet, so that, during the whole period of its growth, the horn, *c*, has around it a tender soft covering, full of vessels, and which is necessary to its growth and support. But when the horn has acquired its full form and strength, this velvet covering is destroyed by a very curious process. At the root of the horn, near the skull, a circlet of tubercles, *d*, called the burr or pearl, is found: the principal vessels run between these tubercles, and, as the tubercles grow, they close in upon the ascending blood-vessels, compress them, and prevent their conveying blood to the horn: then the membrane, which was vascular, becomes insensible and dead, and in time is rubbed off.

In old treatises on hunting, the separation of the outer cuticle, or velvet, is called fraying; and the huntsman, in leading on his hounds upon a hart of many "tines," judges of his size and strength by the fraying-post—the height of the tree against which he has been butting and rubbing his horns to separate the outer covering. The horns, when the velvet is detached, are now perfect. It is after this that the stag seeks the female in the depth of the forest; and now it is that, in encountering his rivals, fierce contests ensue. They dart against each other with great fury, take no repose, and in a very few weeks become quite exhausted. In the museum of the College of Surgeons there are two superb sets of antlers entangled and wedged together: they belonged to two males, which had struck so fiercely against each other that they could not withdraw their horns, and being thus strangely locked together, they starved, and were found dead. The stag is a very different animal, in regard to strength, at different seasons of the year. He feeds, too, on different herbage, sometimes preferring the broom and heath; at another season he resorts to copses, springs, and corn-fields; and these correspond with his different condition as to strength and fatness, and with his passions. It is after the period of contention that the stag is once more found in the copses and underwood, feeding peacefully with his former rivals. And now the process of absorption takes place at the root of the horns, and they are shed: sometimes one is carried a considerable time after the other is fallen; and it is observed that the oldest and strongest harts shed their antlers the soonest. The remarkable circumstance is, that such is the provision, through the absorption at the root of the horn, that a slight shock will now detach that which bore the united force of the two combatants before. The fallow-deer have the same habits and passions; but they will contend in herds for favourite pasture-grounds, and divide into parties under the oldest and strongest of the herd. Who can doubt that the antlers are for a temporary purpose, since, for the greater part of the year, they are either wanting, or in a tender state of growth. Nature bestows them only as arms for the combat which is to decide for the strongest, and give a sire to the herd.

We shall now advert to the forms of the bones of the greater animals, and to those of man. That the bones which form the interior of animal bodies should have the most perfect shape, combining strength and lightness, ought not to surprise us, when we find this in the lowest vegetable production.

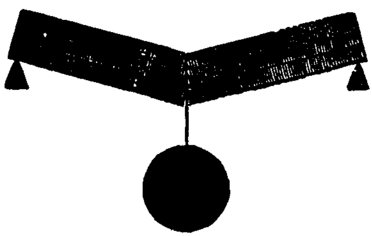
A reed, or a quill, or a bone may be taken to prove that in nature's works strength is given with the least possible expense of materials. The long bones of animals are for the most part hollow cylinders, filled up with the lightest substance, marrow; and in birds the object is attained by means (if we may be permitted to say so) still more artificial. Every one must have observed, that the breast-bone of a fowl extends along the whole body, and that the body is very large compared with the weight: this is for the purpose of rendering the creature specifically lighter and more buoyant in the air; and that it may have a surface for the attachment of muscles equal to the exertion of raising it on the wing. This combination of lightness with increase of volume is gained by air-cells extending through the body, and communicating by tubes between the lungs and cavities of the bones. By these means the bones, although large and strong to withstand



[A, section of the femur, or thigh-bone, to show the hollow of its shaft, and the cancellated structure of its upper and lower ends; *b*, the head, by which it is articulated to the pelvis; *c*, the great trochanter; *d*, the surface by which it is articulated to the leg.]

the operation of powerful muscles upon them, are much lighter than those of quadrupeds.

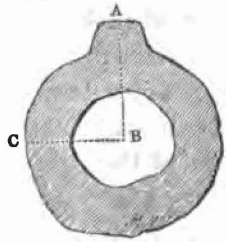
The long bones of the human body, being hollow tubes, are called cylindrical, though they are not accurately so, the reason of which we shall presently explain; and we shall at the same time show that their irregularities are not accidental, as some have imagined. But let us first demonstrate the advantage which, in the structure of the bones, is derived from the cylindrical form, or a form approaching to that of a cylinder. If a piece of timber supported on two points, thus—



bear a weight upon it, it sustains this weight by different qualities in its different parts. For example, divide it into three equal parts (A, B, C): the upper part A supports the weight by its solidity and resistance to compression; the lowest part B, on the other hand, resists by its toughness or adhesive quality. Between the portions acting in so different a manner, there is an intermediate neutral or central part C, that may be taken away without materially weakening the beam, which shows that a hollow cylinder is the form of strength. We may observe a further illustration of this when a tree is blown down and broken at the stem: to the windward the broken part gapes; it has been torn asunder like the snapping of a rope: to the leeward side of the tree the fibres of the stem are crushed into one another and splintered; whilst the central part is bent. This, we presume, must always be the case, more or less. We may observe, too, why the arch is the form of strength. If this transverse piece of timber were in the form of an arch, and supported at the extremities, then its whole thickness, its centre, as well as the upper and lower parts, would support weight by resisting compression.

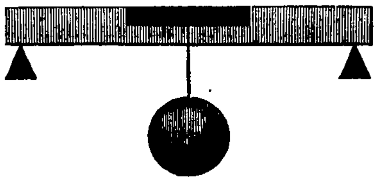
But the demonstration may be carried much farther, to show the form of strength in the bone. If the part of the cylinder which bears the pressure be made more dense, the power of resistance will be much increased; whereas, if a ligamentous covering be added on the other side, it will strengthen the part which resists extension; and we observe a provision of this kind in the tough ligaments which run along the vertebræ of the back.

When we see the bone cut across, we are forced to acknowledge that it is formed on the principle of the cylinder—that is, that the material is removed from the centre, and accumulated on the circumference, thus—



We find a spine or ridge, A, running along the bone, B C, which, when divided by the saw in a tranverse direction, exhibits the irregularity, whereof A is the section.

The section of this spine shows a surface as dense as ivory; that part is, therefore, much more capable of resisting compression than the other part of the cylinder, which is common bone. This declares what the spine is, and the anatomists must be wrong who imagine that the bone is moulded by the action of the muscle, or that the spine is a mere ridge, arising by accident among the muscles. It is, on the contrary, a strengthening of the bone in the direction on which the weight bears. If we resume the experiment with the piece of timber, we shall learn why the spine is harder than the rest of the bone. If a portion of the upper part of the timber be cut away, and a harder wood inserted in its place, the insertion of the harder portion of wood increases this property of resistance. With this fact before



us we may return to the examination of the spine of bone. We see that it is calculated to resist pressure, first, because it is farther removed from the centre of the cylinder, and, secondly, because it is more dense, to resist compression, than the other parts of the circumference of the bone*.

This explanation of the use of a spine upon a bone gives a new interest to osteology. The anatomist ought to deduce from the form of the spine the motions of the limb, the forces bearing upon the bone, and the nature and the common place of fracture; while, to the general inquirer, an agreeable process of reasoning is introduced in that department, which is altogether without interest when the "*irregularities*" of the bone are spoken of, as if they were the accidental consequences of the pressure of the flesh upon it.

* As the line A B extends farther from the centre than B C, on the principle of a lever, the resistance to transverse fracture will be greater in the direction A B than B C.

Although treating of the purely mechanical principle, it is perhaps not far removed from our proper object to remark that a person of feeble texture and indolent habits has the bone smooth, thin, and light; but that nature, solicitous for our safety, in a manner which we could not anticipate, combines with the powerful muscular frame a dense and perfect texture of bone, where every spine and tubercle is completely developed. And thus the inert and mechanical provisions of the bone always bear relation to the living muscular power of the limb, and exercise is as necessary to the perfect constitution and form of a bone as it is to the increase of the muscular power. Jockeys speak correctly enough when they use the term "*blood and bone,*" as distinguishing the breed or genealogy of horses; for blood is an allowable term for the race, and bone is so far significant, that the bone of a running horse is remarkably compact compared with the bone of a draught horse. The reader can easily understand, that in the gallop the horse must come on his fore legs with a shock proportioned to the span; and that in the horse, as in man, the greater the muscular power the denser and stronger is the bone. The bone not being as a mere pillar, intended to bear a perpendicular weight, we ought not to expect uniformity in its shape.

Each bone, according to its place, bears up against the varying forces that are applied to it. Consider two men wrestling together, and then think how various the direction of the resistances must be: now they are pulling, and the bones are like ropes; or again, they are writhing and twisting, and the bones bear a force like the axle-tree between two wheels; or they are like a pillar under a great weight; or those bones are acting as levers. We see, therefore, why, to withstand these different shocks, a bone should consist, as we have stated, of three parts, the *earth* of bone (sub-phosphate of lime) to give it firmness; *fibres* to give it toughness; and *cartilage* to give it elasticity.

We may pursue this subject a little farther still, taking the text of our author—"*The proportioning of one thing to another.*" Chap. xvii. sec. v.

The great functions by which animals live and breathe and are nourished are the same through the whole chain, from the simplest polypus or mass of jelly that floats in the sea, to the largest and most complex of all terrestrial creatures. The appetite for food, the powers of assimilation, circulation, aëration, secretion, are the same functions in all living creatures, only modified by their size or condition. When we consider the astonishing variety in the shapes of animated beings, we are apt to forget the necessity of apportioning their size and strength, not only to the vegetable productions and to the materials found on the surface of the earth, but to the magnitude of the globe—to the "great motions that are passing in the heavens." On that plan of living structure which pervades all the varieties of animals in which bones afford resistance and muscles activity, there must be a limit to stature. The resisting parts of the smaller animals, which have an external covering instead of bones, have comparatively much less material in them than the larger. Accordingly, philosophers have contrasted the power of the flea with that of the horse, deciding greatly in favour of the former. The rationale of this is not quite apparent at first; but a little consideration will convince us, that the resisting material being exterior to the animal's body, and consequently removed from the centre, it must possess more power against transverse fracture, as well as bestow a mechanical advantage for the action of the muscles. But this is not all: any degree of density and strength may be given to it, from its being a mere secretion, and being unorganized. We may compare, however, the bones of man with those of the elephant, or other huge animals.* Now it would seem that the material of bone (which we must recollect is porous, since it consti-

* Vol. i. p. 360.

tutes a living part, and is nourished by blood-vessels) could not, by any variety of conformation, bear up a greater mass than that of the elephant. On examining the bones of these immense animals, including the megatherium and rhinoceros, they are dense and strong, and clumsy, as we would term it; their spines and processes are large, and their cavities filled up: all which indicates, that to support a larger animal on extremities, some other material than the vascular bone would be required. Those immense bones that are found in digging the earth, and which, in ignorant ages, have given rise to strange fancies, are the bones of animals inhabiting the water—whales or reptiles, whose bulk was extended in the water, or that crawled on their bellies, and they could never have given support sufficient to have raised their enormous weight on extremities. With regard to the position, that "a chicken roosting on its perch is related to the spheres revolving in the firmament," I have elsewhere illustrated the necessity of a fixed point from which the muscles can act, and that the necessity of resistance implies that of weight, and that that weight must be proportioned to the mass of the globe we inhabit, as well as to the power of the muscular frame*.

* See the introduction to the Bridgewater Treatise on "The Hand."

III.

DESIGN OR MECHANICAL CONTRIVANCE AS EXHIBITED IN THE BONES OF THE HEAD AND THEIR JOININGS.

We have elsewhere spoken of the "architecture" of the skull, which, though at first a startling term, has been acquiesced in from the remarkable instances that we have given of design, in comparing the texture and connexion of the bones with the art of the builder and carpenter. The more important the part is to life—the more vital the organ, we find the texture or fabric which protects it the more perfect. The human skull presents us with many curious proofs that the forces or injuries to which it is exposed are calculated and provided against. But we shall take our first examples from the skulls of animals; and here we see that the brain is not covered in the same manner in all, but that in each variety there is a provision against the forces to which the skull is subjected. The skull of a dog is hardly in any respect like the skull of a ram; the bones of the former are thin; the line of union, which is called the *suture*, is simple; it is not provided to withstand percussion: but in the latter animal there is reared over the proper brain-case a series of arched cells of strong bone, and each bone is joined to another by a line, serrated, deep and regular; the mechanical strength of the union always corresponding with the strength of the bones; and the whole being formed into a base suited for the support of the horns, and calculated to sustain the shock when the animal butts with the whole weight and strength.

The engraving represents the irregular line of union of the bones of the skull as seen on the outer surface.

We might contrast the skull of the ram or goat with that of the tiger, where the strength is in its jaws. This animal, too, has the brain-case small, and, as it were, buried in the head; but the jaws, instead of being spongy bones, as in man, are dense and strong to sustain the teeth; for what would avail these teeth, long and sharp and strong, could they be twisted from their socket? and what would avail the strength of the jaws, and length and depth of the teeth, were not the proper skull surrounded with spines and arches of bone dense and strong enough to give attachment to the muscles of the jaws? Thus, in the carnivorous animal, the strength of the bony textures of the head is all concentrated in the jaws of the animal, and corresponds with its instinct to hold and rend its prey.

But when the lion or the tiger have struck down their prey—and have gorged themselves and sought their dens, and when the lesser carnivorous animals have cleared the bones—there remains a rich repast which they cannot reach; then comes the hyæna, which cracks the bones, and feeds upon the marrow.

Of all the skulls that can be collected in a museum, the jaws and teeth of the hyæna exhibit the most extraordinary strength: the bones having a clumsy form and dense texture quite peculiar, and suited for the socketing of the strong conical teeth.

We see, therefore, that the fabric of the head, taken as a whole, bears a certain resemblance in all classes of animals; but, though built upon the same general plan, the supports are given to fortify the points which bear the shock.

By such more obvious instances of adaptation we are led to inquire whether any similar adjustment of the resisting property of the bone is to be found in the human head. We must carry this along with us in our inquiry, that a shock or vibration going through the great mass of the human brain proves more immediately destructive of the faculties, than the wound which penetrates the substance without a concussion. When we contemplate the condition of a child, its fearlessness, its restless activity, the falls and knocks it gets, we must perceive that were not the textures of the bones and the brain adjusted, the child when it fell must have lain insensible, instead of rising and crying more from terror than the sense of injury.

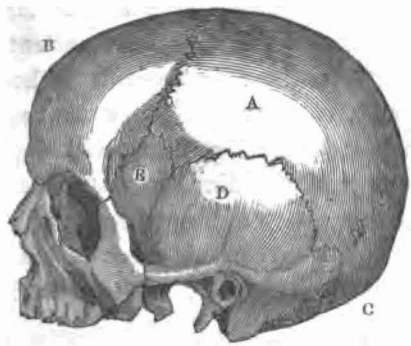
We may contrast this condition of the child with that of an old man losing his balance and falling on his head, who lies insensible from the shock. Is it not apparent that there is here a calculation of the accidents of life, and a provision against them, which yet leaves us threatened with danger, and, therefore, on our guard?

The difference in the textures of youth and age are instructive as to the causes of the diversity. The brain of the old man is firm; the vibration injures its fibre. The brain of the child is soft, and in infancy it may be moulded to any shape. Then, again, the texture of the bone is entirely different, and hardly like the same substance. It is thin and pliant in the child, actually dimpled by a blow; whilst in age it is brittle from its density, and the vibration of the blow runs round it; or if it be broken, it is like a piece of sharp glass entering the tender parts beneath.

Much more than will stand inquiry has been said of the forms of the head, in reference to the contained organs; but there is a simple demonstration which should precede all this: the forms of the skull bear a relation to pressure and injury from without, and the parts most exposed are most protected. A man falling backwards has the back of his head exposed to injury; and the examination and section of the bone at this part shows how nature has strengthened it, by giving it greater thickness and prominence, and by groining it within. We say groining it; for there is nothing more resembling the strong groinings or arches of the ground-story of a great building, than the ridges of the skull at this part of its base, which cross at a centre corresponding with the prominence of the occiput.

In front, the form of the skull exhibits a provision not less distinct in its object. The parts of the forehead which are most prominent and exposed (*eminentiæ frontales*) exhibit, on their section, a thicker and denser bone; whilst the lower part of the forehead is formed of cells or sinuses, which, throwing off the outer wall of the skull from the surface of the brain, still more effectually protects it.

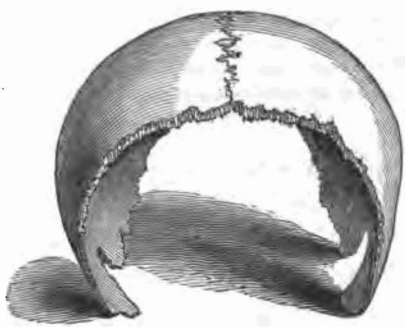
A person tumbling sideways pitches on the shoulder, and the convexity of the head comes to the ground precisely on that point (the centre of the parietal bone) where the bone is thickest and most dense.



A. The *parietal* bone.
B. The *frontal* bone.
C. The *occipital* bone.
D. The *temporal* bone.
E. The *sphenoid* bone.

It is, on the whole, impossible to study the forms of the head without acknowledging that the shape, thickness, and texture of the skull have reference to the liability to pressure and blows from without.

To take a further example:—It seems very natural, in carrying a burden, to poise it on the head. Now, whether we take the carpentry (called a *centering*) on which the stones of the arch of a bridge are laid in building it, or the arch of stone, or a dome—(for with all these the bones of the head may be aptly compared)—there has been nothing ever contrived so perfect as the joining of the bones of the head to resist both pressure above, and straining at the sides. And if, on this subject, we solicit the reader's attention more particularly to these joinings, it is because, in books merely anatomical, they are apt to be treated like things of accident, and described as the running of the fibres of one bone into another, the necessary consequence of their mode of growth; or the accidental effect of the pressure of the muscle: whereas, on the contrary, the



The figure represents the two parietal bones—forming an arch, or a surmounted dome.

finest tools of the carpenter could make nothing so perfect or so demonstrative of design *.

These provisions would surely have met with earlier attention had men contemplated in a true view the object of the animal frame-work; which is not to give absolute safety against inordinate violence, but to balance the chances of life,—leaving us still under the conviction, that pain and injury follow violence: so that our experience of the injury, and our fear of pain, whilst they are the principal protection to life, lay the foundation of important moral qualities in our nature.

* This subject is pursued in more detail in an Essay published by the Society for the Diffusion of Useful Knowledge, under the title of "Animal Mechanics." It is there shown that the bony substance of the skull separates, in the maturity of man, into two plates or tables, and of different degrees of hardness, with an intermediate soft substance; and that by this arrangement of substances of different densities, a shell or covering is given for the protection of the brain, opposing sufficient resistance to pressure, and at the same time calculated to stifle vibration from a blow.

IV.

OF THE JOINTS.

In comparing the skeleton with carpentry, or anything artificial that admits of comparison with it, we remark that, in the bones, there is not a straight line, or regular form, whether they serve as a shaft, axle, or lever; while, in the other, every part is levelled and squared, or formed according to some geometrical curve. This would lead a superficial thinker to conclude that the bones were formed irregularly, or without reference to principle; but the consideration of by Whom formed, leads to a review; and a deeper examination brings with it the conviction that the curves, spines, and protuberances of the bones are formed with a relation to the weight which they bear, and the thrusts and twists to which they are subjected in the different motions of the body.

If we observe the various postures of a man at any manual labour, or under a weight, or running, or leaping, or wrestling, we shall be convinced that no carpentry of the bones, formed upon geometrical lines or curves, could suit all this variety of motion. No splicing, dovetailing, cogging, or any of all the various shapes into which the carpenter or joiner cuts his material, could enable them to withstand the motions of the body, where it is so utterly impossible to estimate the forces, or to calculate upon the variety in the motion.

That the varieties in the forms of the bones are not irregular, nor accidental, but are related to the motions to be performed, is apparent in the close examination of the human skeleton, and still more clearly evinced by comparative anatomy.

The shapes of the bones are very closely related to the motions to be performed by the different joints. Let us observe the enlargement of the diameter of the bone at an articulation. This expansion of the articulated surface of the bone gives power to the binding ligaments, by removing them from the centre of motion; and by the increase of surface and additional strength of ligament, the danger of dislocation is much diminished. The friction of two bodies whose surfaces move upon one another is not increased by the extent of surface, the pressure remaining the same. Hence the enlargement of the surfaces of the joint is attended with greater security without there being additional friction. But, for the most part, the surfaces of the bones, instead of sliding upon one another, have a rounded form, and roll upon each other. Now the friction, in this case, depends upon the diameter of the body which rolls, and is small in proportion as the diameter of that body is great, the weight being the same. By this we see that the large bones forming the knee-joint, for example, have every advantage of greater strength without increased friction.

Our author has perhaps dwelt sufficiently on the smoothness given to the articulating surfaces of the bones by the cartilages and the synovial or lubricating fluid, vulgarly called joint-oil (and ignorantly so called); and after these general observations, in order fully to comprehend the fine adjustment of each bone in its articulation, we should require to go minutely into the anatomy. Then we should find with how curious a mechanical adaptation the motions are permitted in the prescribed direction and checked in every other. We should be called to observe, also, how the motions of one joint are related to those of another; and how, by the combination of joints, each of which is securely checked and strengthened, there is a facility and extent of motion produced by their combination: for example, in the arm and hand, where the motions are free, and varied in every possible direction.

It is interesting to see how the joints of the lower extremities are modified in man in comparison with those of the upper. We have elsewhere remarked that the bones of the human pelvis, thigh, and leg exceed those of all other animals in relative size, which shows a provision for the erect position of man. The same is evinced in the form of the joints, as the ankle, knee, and hip; for whilst their combinations give every necessary degree of motion consistent with security, there is a happy provision, producing at once firmness and mobility. That is to say, when the limb is thrown forward in walking or running, it is loose, and capable of being freely directed; so that we plant it with every convenience to the irregularity of ground: but when the body is carried forward to be perpendicular over that limb, it acquires, by the curious adjustment of the bones, a firmness equal to that of a post. Again, when the body is still further thrown forward, and the limb is disencumbered of the weight of the body, the joints are let loose so as to be bent easily, and to obey the action of the muscles.

V.

OF THE SPINE.

The spine is the most perfect structure in the whole animal machine. Perhaps, if our words were critically taken, it would be better to say, that the intention of the curious mechanical structure here was the most apparent, and on that account most the object of our admiration. By the skeleton is meant the collection of bones which gives form and strength to the superior class of animals; and as these bones are bound together by a chain of vertebræ, the whole class of these animals is called *vertebrata,* from this most essential part of the skeleton. Besides thus binding the bones together, and forming, as it were, the very centre of the whole, the spine is a tube for protecting the most vital organ of all, the spinal marrow. But, again, when we look upon the skeleton of man as giving him the power of standing erect, we observe that the spine, whilst it retains its other offices, has a new one imposed upon it: it is a pillar for sustaining not only the superior parts of the body, but the globe of the head, which we shall find it protects in a very unexpected manner. The reason of our admiration, then, is in being able to perceive the modes by which these different offices are performed by the construction of this column: how nature has established the most opposite and inconsistent functions in one set of bones;—for these bones are so strong as not to suffer under the longest fatigue or the greatest weight which the limbs can bear; and so flexible, as to perform the chief turnings and bendings of the body; and yet so steady withal, as to contain and defend the most material and the most delicate part of the nervous system.

In some animals, the lowest of the vertebrata, the protecting texture of the spinal marrow hardly deserves the name of vertebral column. In certain fishes*, for example, the spine consists of a cartilage made tough by ligamentous intertexture. In the myxine, this cartilage does not entirely enclose the spinal marrow; for it lies in a deep groove on the upper part of the spine. But let us not suppose that in fishes there is any imperfection in the vertebral column: it is an elastic column, on which the muscles act so as to become the means of powerful locomotion; and in all fishes the spine has, more or less, this remarkable elasticity. Ascending in the scale of animals, we find the carti-

* Myxine, lamprey, sturgeon, &c.

lage forming the spinal column subdivided by cavities which contain a gelatinous fluid; and these cavities, being surrounded with a strong but elastic ligamentous covering, nothing can be conceived more admirably adapted to give a springiness to the whole column. Still ascending, we discover that the bony matter becomes deposited between these cavities; and here the separate vertebræ first appear. If two vertebræ of the great shark be taken out together, and the sac between them punctured, such is the elasticity of the walls of this sac, that the fluid will be spouted out to a distance. In other fishes, as the cod-fish (an osseous fish), the structure approaches to that of the mammalia; the intervertebral substance is gelatinous. In the whales, circular concentric ligaments join the vertebræ, and a small portion in the centre consists of a glairy matter. In mammalia, and in man, there are strong and distinct bones of the vertebræ; and these are joined by a ligamentous cartilage, the outer circle of which is remarkably strong, and the central soft and elastic. The toughness and strength of the exterior circle, and the soft condition of the centre, make a joint equivalent in action to what might be produced by a ball intervening between the surfaces: a facility of motion is thus bestowed which no form of solid could give; and yet the joint is so strong, that the bone breaks from violence, but the ligamentous cartilage never gives way. When the veterinary surgeon casts a horse, if he be not careful to restrain him, he will twist himself with a force which will break the vertebræ. It is a frequent accident in man; but the texture that gives mobility to the spine never yields.

The next thing admirable in the spine is the manner in which the head is sustained on a column possessing elasticity, and in which the brain is thereby saved from undue concussion in the movements of the body. This object is not attained altogether through the elastic substance in the spine which we have described; but it is owing, in a great measure, to the general form of the spine in man. Had the vertebræ been built up, like a lofty column, of portions put correctly and vertically over one another, the spine would not have had the advantages which result from the structure that we have to describe. As the incumbent weight would then have fallen on the centres of all the bodies of the vertebræ, they must have yielded in a slight degree only. Accordingly the figure of the italic *ſ* is given to the column, which waving line we need not admire because it is the line of beauty, as some have defined it, but because it is the form of elasticity. The spine being already in a curved shape, it bends easily; the pressure is directed upon the margins of the vertebræ and of the intervertebral substances, and they therefore yield readily; and by yielding, they produce an increase of the curve, a consequent shortening of the whole column, and admit an easy return to their original places. Suppose we rest the palm of the hand upon a walking-cane, which is elastic, but perfectly straight; it bears a considerable pressure without yielding, and when it does yield, it is with a jerk; but if it be previously bent, however we may increase or diminish the pressure, there will be no shock: the hand will be supported, or the cane yield, with an easy and uninterrupted resiliency. Such we conceive to be the end obtained through the double curvature of the spine: that the brain shall receive no shock in the sudden motions of the body.

Were we to give our attention to the processes of bone which stand out from the bodies of the vertebræ, we should find unexpected provisions there also. It is a common remark of anatomists, that the bones of the spine are secured in their proper places by the relations of the surfaces in contact; the surface of the body being oblique in one direction, and those of the articulating processes in another—the one therefore preventing the bone being dislocated forwards, and the others preventing it being displaced backwards. There is something more than this. The articulating processes consist of two broad surfaces, which are inclined in such a manner that they slide upon one another—that is to say, the articulating surface of the vertebra above, being itself inclined, rests upon another which is also inclined. As the intervertebral substances of the bodies yield and recoil, the articulating process of the upper vertebra shifts upon the inclined surface of the process on which it is seated, ascending and descending; but the impediment is greater the more the vertebra descends, thus adding to the elasticity and security of the whole, and preventing the abrupt shocks which would be the consequence of the surfaces being horizontal. If a cannon were made to recoil upon an ascending plane, or a surface forming a portion of a circle, it would represent the mechanism of the articulating processes of the vertebræ.

Let the separate spine be presented before us, it stands up, like a mast, broad and strong below, and tapering upwards. The mast of a ship is supported by the shrouds and stays; and if we sought for an analogy with these, we must fix upon the long muscles of the back, which run along the spine to sustain it. But as a mast goes by the board in a storm, we see where the spine would have been most in danger, had not nature provided against it. When we start forward in walking or running it is by the exertion of the muscles of the lower extremities, and the body follows. Did the spine stand directly up perpendicularly, it would sustain a shock or jar at its base in these sudden motions. We see, therefore, the intention of the lower vertebræ being inclined forwards from their foundation on the sacrum: for by this means, the jar which might endanger the junction of the lowest piece, is divided amongst the five pieces that form the curve. The same thing is seen in the quadruped: for as the spine in the back and loins lies horizontally, and the neck rises towards the perpendicular, there would be danger of dislocation, if the vertebræ of the neck rose suddenly and abruptly from the body: there is, therefore, at the lowest part of the neck a sweep or semicircle formed by the junction of several vertebræ, to permit the head to be erected; a remarkable example of which is shown in the stag.

We have elsewhere observed, that when a delicate piece of mechanism is contrived by the hands of man it may be locked up and preserved. But the most delicate textures of the living frame stand distinguished, above all, by this quality, that if they be not put to use, they very quickly degenerate. Not only is the faculty of action lost by inaction, as every one must be aware takes place in the functions of his own mind, and in the exercise of his senses, but the texture of the organs quickly degenerates. If by accident a limb should lose certain movements, the muscles, nerves, vessels, which nature intended to be subservient to these motions, become in a few weeks or months so wasted that they are hardly recognizable by the anatomist. If we apply this acknowledged principle to the spine, and take along with us that the texture of bone, cartilage, ligament, tendon, muscle, all the parts which enter into its structure and are necessary to its perfection, however varying in solidity or composition, retain their perfection by being exercised, we shall readily perceive the effect of confinement on young females. Without any positive disease, but from being over-educated in modes which require sedentary application, the spine becomes weak and loose in texture, and yields to the prevailing posture, whatever that may be. We mention this because it is a principle important in every consideration to each individual, and applicable to both body and mind.

The French philosophers have entertained the notion that the central parts of all animals are more permanent in their construction, whilst the extremities are subject to variety—a theory partly admitted by some eminent physiologists among ourselves, and which introduces obscurity and hypotheses into one of the most remarkable proofs of design. Dr. Roget, in his excellent 'Bridgewater Treatise,' has taken up this idea.

A spinal marrow belongs to the whole of the vertebrated class of animals; and the spinal marrow must be protected by bone: accordingly, as the principal use of the spine is permanent, so must its form be. Yet whenever there is a change in the action, or rather in the play of the spine, we find the vertebræ conformable. Thus the motion of a fish through the water results from a lateral movement of the tail and spine; but were the constituent bones formed like those of other animals of the same class, the lateral or transverse processes of the vertebræ would interfere with this motion: they are therefore removed, and in order to give strength to the chain of bones, the spinous processes are prolonged towards the back, and corresponding processes project towards the viscera. In the cetacea, as the whale and dolphin, &c., the position of the tail is reversed; it lies out horizontally; and the vertebræ correspond. These animals must rise to breathe the air, and their tails are thus provided to raise them easily to the surface; a proof, if any were wanted, that the spine, the very centre of the system, is accommodated to the main function of respiration.

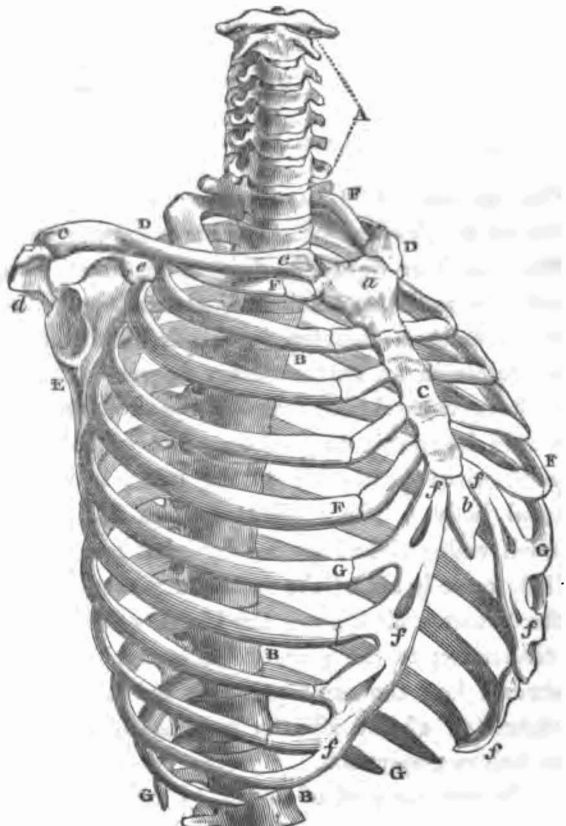
The tail of animals is the prolongation of the spine. But it seems extraordinary that any one should make this the ground of an hypothesis, that when parts are repeated, they become more and more imperfect as they recede from the centre. It is however referred to in view, because the bones constituting the tail become smaller and rounder, and terminate in cartilage in which there is no bone. Is it not, on the contrary, obvious that the tail of animals is constituted for its proper purpose, firm towards the root, with muscles to play it in all directions, and less firm and more elastic towards the end to carry the brush? Can anything be better adapted to such purposes? Would it be more perfect if there were vertebræ instead of round bones joined together? In short, corresponding as this part does with its uses, sometimes as a brush to curl round the animal and be a mantle for warmth, sometimes as a rudder in running, sometimes as a fan, and always reaching where the ear or the tongue cannot reach—must all the obvious provisions be lost sight of in the consideration that animal bodies are constituted so imperfectly, that if a part like a vertebra be formed in the centre, repeated or prolonged, each link, as it recedes from the centre, must become less and less perfect, degenerating from what is presumed gratuitously to be its original form?

VII.

OF THE THORAX AND MECHANISM OF RESPIRATION.

Our author might have made more use of the thorax as affording proofs of his great argument. We have here represented the spine, breast-bone, and ribs, as the anatomist articulates them. Were he to make a skeleton in this fashion, it would be fragile in an extraordinary degree, compared with the natural body; and if the skeleton fell, it would inevitably be broken. Let us see, then, what gives protection to the bones in the natural body. The celebrated John Hunter was much engaged in showing by what means elasticity came in aid of the muscular power, both in the textures circulating the blood, and in those ministering to the play of the lungs. We may observe how the same principle conduces to the protection of the ribs as well as assists their motion in respiration.

The anterior part of the rib (*f*) which ekes out the rib (F G) and joins it to the breast-bone (C), is formed of elastic cartilage; and the rib having a free articulation behind to the spine, it results that each rib is possessed of elasticity. The anatomist making no proper substitute for this in



This drawing has been taken from an artificial skeleton, which is seldom articulated correctly. The ribs do not lie here in a natural position; or, if ever they were placed so in the living body, it could only be in violent inspiration, when they are raised to the very utmost.—[This figure is referred to at p. 137 of Vol. I., but the Number of the Appendix is called VII. instead of VI.]

the artificial skeleton, the bone breaks easily, like a piece of china. We have another proof in the natural body of the necessity for elasticity. We before observed that a child, rash and unsteady, is liable to a thousand accidents to which those of maturer years are not exposed. Now, during all the active years of life, the whole textures of the frame, and especially of the thorax, both bone and cartilage, possess elasticity, corresponding with the hazards to which youth is subject: in short, the child falls and suffers no injury; when an old man, striking his ribs upon the corner of the table, has them fractured. But let us observe the effect of elasticity in the act of respiration.

The ribs do not move to accommodate themselves to the motions of the lungs, but by moving draw the lungs after them, and cause their expansion. The interstices of the ribs being filled up, and a septum closing the thorax below, the enlargement of the cavity permits the lungs to be expanded by the weight of the atmosphere, the air entering them through the windpipe. We at once see the importance of the motions of the ribs, for the expansion of the chest and the play of the lungs. Our author has, however, omitted an essential part of this interesting subject. He has shown that the oblique position of the ribs is necessary to inspiration, and that, by the rising of the anterior part of the rib, the breast-bone is thrust forwards and the cavity enlarged. But the rib has a double motion. It has a motion on its own axis. Suppose a line drawn through the two extremities of a rib, which would represent the string of a bow, that string is stationary, while the bow, representing the rib, revolves; thus the rib, by having its anterior extremity depressed and revolving as it is raised, enlarges the transverse diameter of the thorax as well as the anterior diameter. In this action the cartilage in front is twisted; and the torsion of this elastic matter affects the muscular action in the manner following.

We have understood the act of respiration to be essential to life, and that the expansion of the chest dilates the lungs, gives freedom of circulation through them, and decarbonizes the blood. It is interesting, therefore, to see how a property of dead matter, elasticity, becomes a guard upon life. Every one must feel that it is easier to expire the air than to inspire it; and if we can imagine a person fainting, or in any mode in danger of death, (the very word expiring, in its common sense, implies that the last act of life is the expulsion of the breath,) if the elasticity tends to enlarge the chest, it must tend to the preservation of life, by restoring the circulation through the lungs. This is exactly what happens from the elastic structure of the whole compages of the chest. The elastic property preserves the chest in a middle state. The muscles of inspiration act against the elasticity: the muscles of expiration also act against it: the elasticity tends, therefore, to maintain an intermediate state of dilatation of the thorax; and accordingly the lungs are preserved in a condition to perform their functions for a certain period at least, after the vital actions would have ceased through the muscles, had there been no such structure.

The great physiologist whom we have already mentioned, John Hunter, taught that when one part performed two functions, there was necessarily an imperfection. We have now the most suitable opportunity of controverting that position: for this texture of the thorax is subservient to many different functions. There is no imperfection evinced in the organ of smelling, because in order to draw in the odoriferous effluvia and make them pass over the olfactory nerve, we use the lungs. Nor do we experience any material interference with respiration, because we enjoy the power of speech through an impulse given to the air in expiration. Further, let us attend to the form and expansion of the chest as conducive to the motion and strength of the arm and hand. The motions of the superior extremity result from muscles which lie upon the chest; and were it not for the expansion of the chest, from the contained atmospheric air, these muscles would not act with sufficient power, or a substitute must have been found either of projecting bones, or of some solid texture, to afford lodgment and attachment to these muscles.

Then, again, considering man in his natural condition, the chances of life would run against him if he were incapable of floating upon water, or if the atmospheric air in his body were not anterior to his centre of gravity. The force of this argument will be understood when we remember that the air contained within the lungs, after a man has made an inspiration, amounts to three hundred and thirty cubic inches.

Looking to the means of guarding life, nothing can be more important than the condition of the lungs, in respect to the atmospheric air within them. The sensibility, and the rapid contraction of the glottis, which is at the mouth of the respiratory tube, is for the purpose of arresting any foreign matter afloat in the atmosphere, which might be drawn in by the stream of inspired air, and so reach the recesses of the lungs. But were this all, the office would be but half performed.

The foreign body would be arrested; but how would it be expelled if it lodged? In common expiration the air is never expelled altogether from the lungs: there is enough retained to be propelled against this foreign body, and to eject it. And, but for this, the sensibility of the glottis, and the actions of the expiratory muscles, would be in vain; we should be suffocated by the slighttest husk of seed, or subject to deep inflammation by the collection of foreign matter drawn into the air-tubes.

We may here observe, that the instinctive actions for the protection of the body are calculated, if we may say so, for the natural condition of man. The manufacturer is sometimes removed from that condition; and our invention must be taxed, not only to maintain the purity of the atmosphere in which he works, in a chemical sense, but to arrest, or convey away, the small portions of material which may be thrown off by the operations of the flax-dresser, for example, in heckling, or of the cutler, whose occupation it is to grind the steel after the instrument is forged, or of the stone-cutter, &c., and so to prevent those particles being inhaled. The length of the passages which lead to the lungs, the sensibility and muscular apparatus bestowed upon them, and the mucous secretions thrown into them, are the natural means by which foreign matter is arrested and thrown out. But in these artificial conditions of men, insoluble particles are continually floating in the atmosphere which they breathe; these are drawn in and lodge in the lungs, and irritate to disease.

The reader will find that the following extract, from a paper upon the actions of the windpipe, illustrates the present subject *.

"We read that the trachea is formed of imperfect hoops of cartilages joined by membranes, and that it is flat on the back part for these reasons: that it may be a rigid and free tube for respiring the air; that it may accommodate itself to the motions of the head and neck; and that it may yield in the act of swallowing to the distended œsophagus, and permit the morsel to descend. This is perfectly correct: but there is a grand omission. Whilst all admit that a copious secretion is poured into this passage, it is not shown how the mucus is thrown off.

"There is a fine and very regular layer of muscular fibres on the back part of the trachea, exterior to the mucous coat, and which runs from the extremities of the cartilages of one side to those of the other. This transverse muscle is beautifully distinct in the horse.

* Philosophical Transactions.

"When a portion of the trachea is taken out, and every thing is dissected off but this muscle, the cartilages are preserved in their natural state, but the moment that the muscular fibres are cut across the cartilages fly open. This muscle, then, is opposed to the elasticity of the cartilages of the trachea. By its action it diminishes the calibre of the tube, and by its relaxation the canal widens without the operation of an opponent muscle.

"The whole extent of the air-passages opens or expands during inspiration, and then the trachea is also more free; but in expiration, and especially in forcible expectoration and coughing, the trachea is diminished in width. The effect of this simple expedient is to free the passage of the accumulated secretion, which, without this, would be drawn in and gravitate towards the lungs. When the air is inspired, the trachea is wide, and the mucus is not urged downwards. When the air is expelled, the transverse muscle is in action, the calibre of the tube is diminished, the mucus occupies a larger proportion of the canal, the air is sent forth with a greater impetus than that with which it was inhaled, and the consequence is a gradual tendency of the sputa towards the top of the trachea. In the larynx the same principle holds; for as the opening of the glottis enlarges in inspiration, and is straightened in expiration, the sensible glottis, by inducing coughing, gets rid of its encumbrance. Without this change in the calibre of the trachea, the secretions could not reach the upper end of the passage, but would fall back upon the lungs.

"Experiments have been formerly made by M. Favier, which, although no such view as I now present was then in contemplation, prove how the action of the transverse muscle tends to expel foreign bodies. The trachea of a large dog being opened, it was attempted to thrust different substances into it during inspiration, but these were always sent out with impetus, and could not be retained. Why the dog could not be thus suffocated is apparent: the tube is furnished with this most salutary provision to secure the ready expulsion of all bodies accidentally inhaled—the air passes inwards by the side of the foreign body, but, in its passage outwards, the circumstances are changed by the diminished calibre of the canal, and the body, like a pellet filling up a tube, must be expelled by the breath."

We have, perhaps, pushed the inquiry far enough; and yet the interest might be increased by observing the manner in which the textures of the ribs are accommodated to variations in the mode of respiration, or to the necessity of the animal expressing the air from the lungs in diving. We have seen how the thorax is expanded in birds to the whole extent of the body, for obvious reasons; and the counterpart of that is presented where the animal, instead of being buoyant in the atmosphere, has to dive into the water and crawl at the bottom—not at great depths, but yet under water, in shallow pools and marshy places. The frog has no ribs; and its mode of respiration shows a complete change from that of animals which breathe with a diaphragm. It has the power of compressing its body, and expelling the air from the lungs; and were it not for this, the animal would remain on the surface of the water as when cruel boys blow them up with a straw. The crocodile and other saurian reptiles have their ribs accommodated so as to produce a similar effect, and for a similar purpose. Instead of the arched form of the ribs, which we have described as capable of a slight change of figure only, they have ribs composed of distinct pieces, and jointed in such a manner as to enable them to compress the chest into a smaller volume.

We have a sort of exposition of the uses, if not the necessity, of respiration to the voice, in observing by what substitutes sound is produced, for example, in insects, which do not breathe by lungs. And indeed, the same consideration suggests the inquiry as to the means by which the atmosphere is agitated, in the same class of animals, in subservience to the sense of smelling.

VII.

THE SUBJECT CONTINUED WITH REFERENCE TO THE CAPACITY OF THE CHEST, AND ITS CONDITION DURING BODILY EXERTION.

We must approach this part of our subject by the consideration of that law of fluids which appears, at first, so contradictory as to be called the "hydrostatic paradox."

Suppose a machine formed of two boards of equal diameter, and joined together by leather nailed to their margins like a pair of bellows: a hole is made in the upper board into which is inserted a tube. Now, if a person mount upon this apparatus when it is filled with water, and blow into the tube, he can raise the upper board, carrying himself upwards by the force of his own breath—indeed, by the power of his cheeks alone. It is on the same principle that, when a forcing pump is let into a closed reservoir of water, it produces surprising effects. The piston of the hydraulic press being loaded with a weight of one pound, the same degree of pressure will be transmitted to every part of the surface of the reservoir that is given to the bottom of the tube, and the power of raising the upper lid will be multiplied in the proportion that its surface is larger than the diameter of the tube. Or, to state it conversely: suppose we had to raise the column of water in the tube by compressing the reservoir, it would require the weight of a pound on every portion of the superficies of the reservoir equal in extent to the base of the piston, before the water could be raised in the tube. If the apparatus which we have described were full of air instead of water, we should witness a similar effect; for all fluids, whether elastic or not, press equally in all directions; and this is the law on which the phenomenon depends. If we blow into the nozle of a common pair of bellows, it is surprising what a weight of books we can heave up if laid upon its board.

Understanding, then, that the power of the hydraulic press, in raising the lid, depends on the size of the reservoir, and its relation to the tube; and again, that in pressing the fluid up through the tube, the pressure upon the sides of the reservoir must be the greater the larger the cavity, we can conceive how a glass-blower propels the air into his blow-pipe with great ease, if he blows with the contraction of the cheeks, the smaller cavity;

but with an exhausting effort, if he blows by the compression of the larger cavity, the chest. Dr. Young made a calculation, the result of which was, that, in propelling the air through a tube of the same calibre, a weight of four pounds operating upon a cavity of the size of the mouth would be equal to the weight of seventy pounds pressing upon a cavity of the dimensions of the chest.*

Let us see how beautifully this hydraulic principle is introduced to give strength in the common actions of the body. We have remarked that the extension of the superficies of the thorax is necessary to the powerful action of the muscles which lie upon it; and these are the muscles of the arms. We must all have observed, too, that in preparation for a great effort, we draw the breath and expand the chest. The start into exertion, and of surprise, in man and animals, is this instinctive act. But unless there were some other means of preserving the lungs distended, the action of those muscles which should be thrown upon the arms,

* The action of one who uses the blow-pipe is rather curious. The mouth is distended with air, and the passage at the back of the mouth closed; the man breathes through the nostrils, but, from time to time, admits a portion of air into the mouth in expiration. The pressure into the blow-pipe is from the distension and consequent elasticity of the cheeks, occasionally assisted by the buccinator muscle, or trumpeter's muscle, so called because it compresses the distended cheeks. In this way the stream of air through the blow-pipe is kept up uninterruptedly, whilst the man breathes freely through his nostrils.

would be wasted in keeping the chest expanded. It is here, then, that the principle which we have noticed is brought into play. The chink of the glottis, which the reader has already understood to be the top of that tube which descends into the lungs, is closed by a muscle not weighing a thousandth part of the muscles which clothe the chest; and this little muscle controls them all. A sailor leaning his breast over a yard-arm, and exerting every muscle on the rigging, gives a direction to the whole muscular system, and applies the muscles of respiration to the motions of the trunk and arms, through the influence of this small muscle, that is not capable of raising a thousandth part of the weight of his body: because this little muscle operates upon the chink of the glottis, and is capable of opposing the whole combined power of all the muscles of expiration. It closes the tube just in the same way that the man standing on the hydraulic bellows can with his lips support his whole weight. Thus it is that the muscles which would else be engaged in dilating the chest are permitted to give their power to the motions of the arms.

Some cruel experiments have been made, and, for whatever intended, they illustrate the necessity of closing the top of the windpipe during exertion. The windpipe of a dog was opened, which produced no defect until the animal was solicited by his master to leap across a ditch, when it fell into the water in the act of leaping; because the muscles which should have given force to the fore-legs lost their power by the sudden sinking of the chest. The experiment is sufficiently repugnant to our feelings; and I need not offend the reader by giving instances in further illustration from what sometimes takes place in man.

VIII.

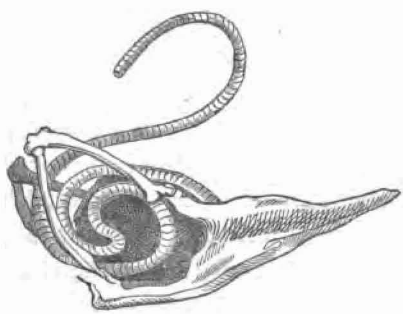
THE RELATION OF THE BODIES OF BIRDS TO THE ATMOSPHERE.

THE first object noticed in Chap. xvii. is the wing of a bird; and this is given as an instance of *the relation of the animal body to the elements by which it is surrounded.* We entreat our readers' attention to the philosophy of this subject. And let us not be contented with admiring the structure of the feather, or the adaptation of the bones of the wing to their office, but let us go deeper into the inquiry: it is a subject which will reward us.

Let us take it for granted that a creature is to live by the exercise of the same functions with the races of mammalia or quadrupeds, as digestion, assimilation, respiration, &c.; but that it must rise in the air and seek its food by long flights. What are the circumstances necessary to this new condition? Is it not obvious that the creature must be specifically lighter or more buoyant in the atmosphere?—that instead of its muscular system being divided and directed to the movement of four extremities, it must have its strength principally directed to the wings, that it may extend them and be able to raise its body upon them?

Let us then see how this is accomplished, and how the original animal economy is interwoven with an entirely new machinery of motion.

The first object will be attained by enlarging the body of the bird, without increasing the weight in anything like the same proportion—and one very obvious means will be found in extending the trachea or windpipe. In examining the tame and wild swan, the most careless observer will detect the provision for flight in the latter, by the conformation of the windpipe which is curiously convoluted within the sternum or breastbone.

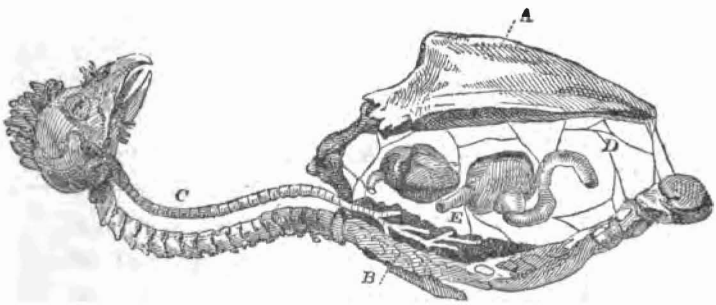


This sketch from the male crane will illustrate what we mean. The light and hollow air-tube fills a space in the interior of the bone, by which the surfaces are extended for the attachment of the muscles of the wings, and thus two objects are attained through it.

In attempting to explain the reason of such deviations from the common forms of parts, we are liable to fall into the same mistakes as we find occasionally in commentators on the Sacred Volume. Were we seeking for the varieties of the organs of voice, we might here start to the conclusion that we had found in the animal body a complex instrument resembling a trombone or Siberian hunting horn; but by further inquiry we should discover that some of those birds that have the most complex and varied windpipe have no cry at all.

But there is a still more curious provision for the extension and magnitude of the body of a bird, independently of weight. In birds the air does not only pass into their lungs, but through them, so as to fill a series of air-cells, composed of fine membranes which are interwoven with all the viscera. The heart is surrounded by such a cell. Two great cells are attached to the liver, and in the same manner are all the viscera of the abdomen interspersed with air-cells, and these all communicate. The air thus admitted into the interior of the body, extends even into the bones. Naturalists have mistaken the end of this structure when they have represented it as a developement of the respiratory organs. It is not to make the function of respiration more perfect that the air enters so extensively into the body; as a proof of which, the air in the bones of the head is supplied through the nasal cavities and Eustachian tubes, independently of the lungs altogether *.

Mr. Hunter has shown us, that in many birds the internal air-cells communicate with the exterior cellular membrane, especially in the neck and axilla, which marks an analogy with the air-cells under the skin of the bat. Winged insects, too, have their bodies extended by air-cells communicating with their respiratory apparatus. These facts sufficiently evince the object of Nature in this extension of the air-cells; that it is not for the purpose of breathing, but for enlarging the volume of the body without increasing the weight.



* Mr. Hunter's 'Animal Economy.'

We must observe the very peculiar mechanism of the bird's respiration. The breastbone or *sternum*, A, runs the whole length of the animal's body, and the great central spine of that bone called the *keel*, rises from it, so as to give lodgment and attachment to the great muscles of the wings. It will be easily understood how naturalists distinguish birds of passage by the size of the keel (crista), since its greater prominence implies strength of wing for long-continued flight. Under the breast-bone, and between it and the backbone, we perceive the space occupied by air-cells. The lungs, B, lie behind; and by the motion of the bone A, like a great bellows, the air is drawn through the lungs, and through the windpipe, C, into the cells D, E; at once effectually oxygenating the blood in the lungs, and renewing the air within the recesses of the body.

The next thing remarkable is in the vertebræ of birds—for the backbone is in its constitution unlike that of man or quadrupeds. The back is firm and the caudal extremity loose and moveable. The first is obviously intended to give a fixed origin to the muscles of the wing, and the second to afford motion to the tail. It is by the wings they raise or propel themselves, and by the tail they direct their flight. We need hardly add that there is a change in the centre of gravity compared with that of animals; in birds the centre is between the wings.

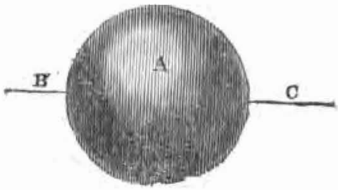
If our reader has followed us in these details, he will acknowledge that there cannot be a more curious instance of a change and adaptation of the whole system of the living body to the external elements, than is to be found in the system of birds.

IX.

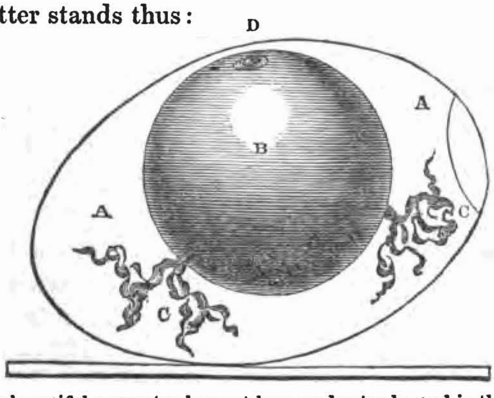
MECHANISM OF THE EGG, OR REVOLVING OF THE YOLK.

The illustration used in the Preliminary Discourse, of the manner in which the cicatricula, containing the chick within the egg, is presented to the breast of the hen, requires the following diagrams in explanation.

When we hold an egg steady, and chip it at the upper part, we find the yolk close to the shell; and on its upper surface a pale vesicle, the cicatricula, which contains the embryo chick. When the hen sits, the heat of her body developes the action of the living principle in the embryo, and on the second and third day a little zone of blood-vessels appears; these vessels run towards the embryo, and carry nourishment to it; and day by day we may watch its sensible growth. From the delicacy of this action we may perceive how necessary it is that the embryo at this early period should be close to the breast of the hen, and not at the cold bottom of the nest. We shall now see how it is accomplished. The yolk is a globe of nutritious matter, and the little vesicle with the embryo is involved in the surrounding membrane, and consequently, as we have said, is at the surface of the globe. If this globe had the axis of its revolution thus, in the centre, it would



not move with the change of the position of the egg. But the axis being below the centre, it must turn round with every change in the position of the egg, whether the globe be heavier or lighter than the surrounding white: were it heavier, it would revolve so as to bring the embryo to the lower part of the shell—were it lighter, to the upper part of the shell. It is lighter, and the matter stands thus:



This beautiful apparatus has not been understood; and in the last publication which touches on the subject the yolk is supposed to be heavier and to hang upon the chalazæ.

A A, is the white of the egg; B, the yolk; C C, the treddles or chalazes; that tough matter which we find in eating an egg little boiled. Each of these bodies is connected with the white, and attached at a point to the yolk. The yolk being as it were anchored at these two points, and the attachments being below the centre, and the yolk being lighter than the surrounding white, it revolves like a buoy, and the cicatricula containing the embryo D is thus kept always uppermost.

If "the chicken roosting on its perch be related to the mass of the globe and the earth itself," as our author has affirmed, what may we say of the revolution going on within the egg?

X.

OF THE TEETH OF ANIMALS—THEIR MECHANICAL PROVISIONS.

THE teeth form a subject of much higher interest than will at first be readily imagined. There is no part of an animal body where 'contrivance' is more distinctly demonstrated, or in which a resemblance is more obvious between the mechanism of engines and the provisions in the animal mechanism. Suppose an instrument were to be ingeniously contrived to cut like an adze, or to divide like a pair of shears, or to grind like a mill-stone, or to hold like a mousetrap*, or to tear,—what, after a period of working, would be the condition of these machines? Would not the edge be blunted—the sharp points become rounded—the grinding surfaces smoothed?—and would not the teeth of the machine be driven deep into the sockets, and so render it wholly useless? But nothing of this kind takes place in the teeth of animals. They are perfect for their purpose, and, if duly exercised, last the natural term of life, however the period of natural decay may vary in different animals.

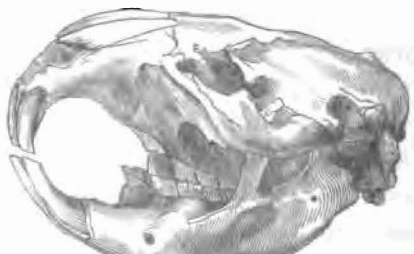
* As in the gullet of fishes.

To commence with the manner in which the teeth resist pressure into the jaw. If we look to the teeth of the lion, we find their roots conical and socketed, as if a nail were driven in; and so it is in the remarkably strong teeth of the hyæna.

The figure represents the back tooth of the Tiger's jaw, which closes like the blade of scissars.

Now these animals have powerful muscles, closing the jaws with a force to break the strongest bone. How is it, then, that the teeth are never pressed deeper into the jaw. For undoubtedly this would be the effect in an engine so constructed by man's ingenuity. The reason is, that there is a living property in the teeth and jaw, by which the former are made to protrude from their sockets, in proportion to the pressure to which their crowns, that is, their exposed parts, are subjected. It is very remarkable that the teeth during their period of growth, notwithstanding they are exposed to the pressure of mastication, will ascend or protrude more and more out of the jaw; and when fully grown, they will remain stationary and on a level, if subjected to the natural pressure of mastication; but without this they will rise too high, project, and at last fall out. It is on this principle, that if we lose teeth in one jaw, we lose them in both: and there are no means of preventing the loss of these, but by such mechanical substitutes as shall restore them to their due exercise. And yet Nature modifies the law with perfect ease, and, as it were, at will. Let us take an example:

The front teeth of the horse are called "nippers;" they meet, and crop the herbage. As the horse is a vegetable feeder, he must grind with his back teeth, and during this act, the front teeth must participate in the grinding motion. We shall presently see how they are protected against this attrition. But in the ruminant animals, those which chew the cud, there is a necessity for a more thorough grinding of the food, whilst at the same time the front teeth must preserve their edge. For this purpose, the teeth are wanting in the fore part of the upper jaw, and there is only a cushion, which embraces and holds the grass against the edge of the lower teeth, so that it is cut as with a sickle, by a smart twitching motion of the head. Thus the front teeth undergo no attrition. Now, although there be no teeth in the upper jaw, those below do not rise or become loose, as they certainly would in man, or in any other animal, not of the class of ruminants. This reasoning will be more satisfactory than the statement, p. 218. Two objects are here attained:—first, that the cutting teeth are preserved sharp; and, in the second place, these teeth differ in their condition from ours, since they do not rise in consequence of wanting opponents.



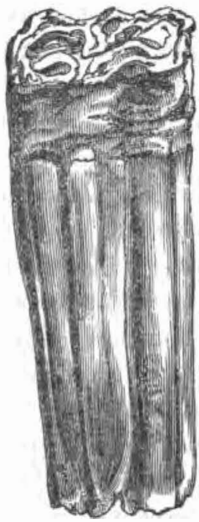
The figure represents the skull of the Beaver, to show the nature of their cutting teeth.

In the class of rodentia or gnawers, the front teeth must cut with a sharp edge. We know how this is contrived in the tool of the carpenter; and we know also that he must from time to time apply his chisel to the grindstone. The front teeth of the beaver, the porcupine, and the rat, are sharp and yet not blunted by use; the bone of the tooth is the densest possible, consistent with the material: but were the whole tooth of the same material, it would be ground down uniformly, and the original form of the instrument would be lost. Accordingly, a different substance, the enamel, which yields more slowly to attrition than the bone of the tooth, is, as it were, let in on the anterior surface of the tooth. The consequence is, that the enamel stands up sharp and exposed, so as to protect the bone of the tooth, and to give the surface which is worn down a certain shape, viz. that original shape suited to cut like an adze. The attrition and the arrangement of the material of the tooth so far correspond, that the cutting form is preserved, however much the surface may be worn down.

Now a tooth cannot grow; and as we have seen that it is wasted by friction, how is the cutting edge to retain its place? When the steel plate of the carpenter's plane is forced in by repeated taps with his hammer, he projects the sharp edge, and when it is elevated above the plane in a just degree, he fixes it there by a smart blow on the wedge: but the cutting edge of the chisel-like incisors of the rodentia is still more finely adjusted.

In the first place, the tooth is very long, extending the whole length of the jaw, and it is of a curve not easily described, not partaking of any section of a cone; still it is so adapted that the cutting edge meets its opponent tooth, and although incessantly wasted, it is accommodated to the growing jaw. We have said that a tooth does not grow. It does not grow like a bone; but sometimes additions are given to it at the root; such is the case in this class of animals: the tooth of the gnawer is thus pushed on along the jaw, owing to the growth taking place at its root and in its proper curve: so that the cutting edge is protruded in proportion as it is wasted in the process of attrition and sharpening. This is a mode of growth which takes place in no other animal's incisor tooth.

Let us now observe how the grinding surface of the tooth of an herbivorous animal is composed. It must be rough or irregular, so as to catch the grain. A smooth millstone, for example, would not bruise the grain into meal. The burr-stone, accordingly, is sought for the nether millstone. This stone contains small portions of feldspar, imbedded in a softer material: and thus, however the surface may be ground down, the harder material, by yielding less easily to friction than the softer, projects above the general level, and preserves a roughness of the surface even whilst it is yielding. It is exactly so with the tooth of a graminivorous animal. It is composed of alternate layers of the hardest bone, or rather of ivory, and a denser material still, the enamel. The consequence of this inequality in the composition is, that notwithstanding the surface of the tooth is worn down, the roughness is preserved.



The figure represents the molar tooth of the horse, and exhibits the roughness of its upper surface, and the depth of the body of the tooth in the jaw commensurate to the pressure it bears.

There is something curious too in this irregularity, showing that it is as far as possible from accident. The lines of enamel which stand up differ in their arrangement according to the motion to be given to the jaw. In the horse and cow, these ridges run parallel with the jaw, and consequently lie across the direction of the motion of chewing, which is from side to side. In the rodentia, on the other hand, the line of the enamel of the grinding teeth runs transversely to the jaw; and in mastication, the jaw is drawn backwards and forwards, not laterally. This original composition of a grinding tooth is, therefore, superior to the best millstone. The roughness, which is so like a thing accidental, is found to proceed from an arrangement in accordance with the motion of mastication. It might, in like manner, be easily demonstrated, that there exists a similar accordance with the form of the jaw and with its articulation; but the instances already given of adaptation may suffice.

Before leaving the subject of the provisions against the wasting of the teeth by friction, there are one or two circumstances of a very interesting nature to be noticed. The elephant is a graminivorous animal, and requires to grind its food very thoroughly. What then must be the provision in the grinding tooth of this animal to withstand the power of its jaws? We find the teeth, in fact, formed of three substances, and, we may say, of a structure superior to the teeth of the lesser graminivorous animals, of course admirably suited to resist the action of chewing. But there is a circumstance peculiar here. Although the matter of the tooth once formed does not change, an alteration in the position of the tooth in the jaw may produce a similar result. When the great grinding tooth of the elephant appears first above the jaw, the anterior corner only projects: but as that becomes worn down, the tooth, by revolving on its centre, presents in slow, but regular succession, more and more of the surface, guarded with new plates of enamel, until it is at last worn to the roots. Here, then, we have a new and extraordinary provision against attrition in the teeth of an animal which lives to a great age. The structure of the tooth itself has a very large proportion of enamel, in dense and regular ridges: but as if the material of the teeth could be brought to no greater perfection to withstand the chewing, it is "contrived," for we have licence for such language in our author, that the tooth itself shall undergo a revolution, not being simply elevated from the jaw, but turning on an axis.

There are other modes in which Nature counteracts the wear and tear of the engine; and the provision which we have now to mention supplies not only a substitution of more perfect teeth for those that are injured, but teeth of a size as well as form suited to the growing jaw. In the crocodile, for example, the teeth are conical and sharp; but if not worn, they must be torn away, and there is a necessity for a succession. It is thus provided: under the exposed tooth, there is another one lodged, of the same shape; and under that, a second and a third. Each tooth, as it is deeper in the jaw, is larger in its base, and longer and stronger. So it happens, that when a tooth is torn off, it is only the uncapping of a sharper and a stronger tooth.

The same end is attained differently in other creatures. In the rays, such as the skate, and in the shark, the succession of the teeth is still more curiously managed. The jaws resemble a part of a cylinder, studded with many rows of teeth. The teeth of the outermost row being in use are liable to be torn off or worn down; when this occurs, their places are supplied by a revolving of the solid base on which the teeth are studded, and the posterior ranges advance in succession. Here, then, we not only find sharp and cutting teeth, like those of a saw: but, corresponding with the boldness and voracity of the animal, we see a provision for their rapid renewal.

It is interesting to see how the same class of parts may be modified, and yet retain their original destination of supplying the stomach with food, and preparing it for digestion. What teeth could we suppose suited for the whale? Now the largest species of whale feed upon a small molluscous animal which abounds in the northern ocean. The teeth are here, we may say, converted into a substance like horn; with which we are familiar under the name of whalebone. They consist of plates of this whalebone attached to the upper jaw, and placed in rows on the outer margins. Their loose edges terminate in a fringe, as if the plates were split and teased into shreds; and this is undoubtedly for the purpose of retaining the small fry, while the water is drained through their interstices.

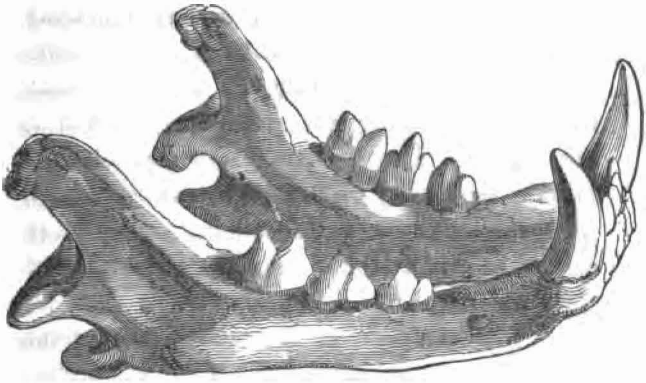
In this curious apparatus there is, of course, no necessity for great strength in the jaw, nor for very powerful muscles to move them. The head of the animal needs not, therefore, be denser in its texture, nor less buoyant than the rest of the body. What would be required if any of the species had jaws or teeth at all corresponding with their size? They could not lie horizontally:

their head would, from its weight, be depressed, and their tail elevated towards the surface of the water. We need not, however, strain our ingenuity to say what would be required; for Nature has demonstrated how this defect is to be remedied. The spermaceti whale, which has teeth, has also cavities in its head filled with a material much lighter than water, the spermaceti; and this counterpoises the weight of the teeth and jaws, and restores the equilibrium of this cetaceous animal.

We have, perhaps, said enough on this part of our subject. But as we have seen how strangely the teeth vary, to be adapted to their office of cutting and grinding, we may observe that they are sometimes adapted to different purposes.

The common classification of the teeth is into incisors, canine, and molar or grinding teeth. Let us take our example from the canine teeth. In man, they are of great length and strength: their fangs project deep into the upper jaw; they are called the eye-teeth; and they tend to sustain and give strength to the range of the incisors. In the carnivorous animal, they are called "laniarii;" they are for tearing and holding; for which purpose, there is a correspondence between them and the hooked claws.

The tusks of the elephant are of this class;



The figure of the lower jaw of the Tiger.

and between these, the tender trunk is protected. In the boar, the canine teeth project, and become powerful instruments, not for biting, or holding, or tearing, but for rending or rather cutting: that is, the whole force of the animal in its rush is directed to give effect to the tusk. So little are the tusks calculated for biting, that the tusk of the lower jaw closes in upon that of the upper jaw, so as to support its base, and to give it strength commensurate to the power and impetus of the animal. But we must not suppose that the tusks are solely for the purpose of offence. The strength and the power of the neck of the boar is mainly for the purpose of ploughing up the earth and rooting up herbs by means of its tusks.

In some animals, as the babyroussa, this tooth rises and twists so as to make it at first sight appear useless. Certainly the tusk is neither for holding, tearing nor masticating; yet it is not useless. This animal escapes from his enemies by the facility with which he rushes through the brushwood; and these teeth are curiously calculated to bear aside the branches and to protect the eyes.

In other animals, as the walrus, the canine teeth of the upper jaw become tusks, but project in an opposite direction to those of the elephant. They enable the animal to raise itself out of the water, by holding on upon the rock or iceberg, as the parrot steadies himself by the bill.

XI.

THE SUBJECT PURSUED WITH REFERENCE TO THE FORMATION AND GROWTH OF TEETH.

SEEING how admirably these instruments have been adapted to their several uses, the reader must be curious to know how they are produced—how they are manufactured with so fine a "prospective contrivance." Three different substances are exposed on making the section of a tooth; viz. ivory, or the bone of the tooth—the enamel, which is very hard, and breaks with a vitreous fracture—and a substance differing in some respects from both, and which English anatomists have called crusta petrosa, and Cuvier cement. These three substances are not formed in every tooth. Some teeth consist entirely of the bone or ivory, as those of the porpoise and bottle-nosed whale. In man, and in the carnivorous animals, the bone is covered with enamel, and in the graminivorous and ruminant animals, all three substances are found.

In the chapter on bone, it has been shown that its texture must be loose to admit blood-vessels; for bone is nourished and undergoes changes through the influence of the circulating blood in it. But the almost stony density of the teeth does not admit of circulation within them; yet they possess life, and through that principle are in union with the gum and jaw. A dead tooth, however pure and perfect, when thrust into the socket of the jaw, remains there no longer than would a peg of wood or of metal. It causes inflammation and pain, and is thrown out.

It would be a difficult question for those who consider life to be the result of organization to solve, how a principle of life should exist for a term of years, giving rise to a sympathy and union with the jaw, in a part like the bone of a tooth, which has neither what they call organization nor any circulation of blood in it. Here we have one of those inscrutable qualities of life which makes physiology a science distinct from all others; and it is an example of there being adaptations far more admirable than merely mechanical appliances.

But we were about to show how the different portions of a tooth are formed. In the jaw of the young animal a sac is discovered, which contains the rudiments of the tooth. On opening the sac, we think we see the tooth, but it is only a body of the form of the crown of the tooth, and is soft to the touch. This is called the *pulp* of the tooth; although pale at first, at a stated period it becomes full of blood, and then the bone of the tooth begins to be formed; and now, on touching it, we can lift from it a delicate shell, which is at once of the form of the pulp, and of the perfect tooth. The process thus begun is completed by the secretion of successive strata from the surface of the pulp, until the bone of the tooth, which was at first a mere scale, becomes a dense body, with a small cavity and tube leading to it; and the pulp, which was of the size and shape of the tooth, shrinks to a mere shred, containing a nerve and vessels.

Thus the original use of the pulp is changed: but it remains, serving an important purpose; for by sustaining a sensible nerve within the tooth, it extends a degree of protection to it. The teeth are sensible to what we masticate; they are sensible to the smallest particle of sand, and so are they to the degrees of heat. This sensibility is necessary to their protection, and to the continuance of their vitality, yet the sensibility is not in the substance of the tooth, but in the nerve within; and the density of texture of the tooth becomes a medium through which both mechanical vibration and heat are readily communicated to the nerve.

We have seen how the bone of the tooth is secreted by the pulp. The enamel is formed differently. The sac, which covers the whole pulp and rudiments of the tooth, has a fine organization, as displayed by the art of the anatomist, and its inner surface throws out a fluid which, falling on the surface of the bone of the tooth, (already formed by the pulp,) there concretes, or undergoes a species of crystallization, and hardens into enamel.

The difference between the bone and enamel of a tooth, that is, between what is formed by the pulp and by the sac, is shown by a very simple process. When a tooth is immersed in diluted nitric or in muriatic acid, the enamel is dissolved with effervescence, and is completely carried away; but when the earth of the bony part is dissolved, it leaves behind it a cartilaginous matter, which constituted a part of the bone of the tooth. In its chemical composition the bone of the tooth resembles the bone of the skeleton, though not strictly and anatomically, as it wants the vascularity of true bone; it is therefore, with more propriety, called ivory.

We have still to explain how the compound teeth of the vegetable feeders are formed. Now, if we comprehend the means employed in the simple tooth, we shall have little difficulty in understanding this. The pulp is divided, and consists of parallel layers joined below, but free above, and with considerable interstices. These divisions or processes of the pulp secrete the ivory upon their surfaces, by which, of course, plates of this dense material are formed on each side of the soft processes or tongues of the pulp. There will therefore be double the number of plates of bone that there are processes of the pulp.

Each plate of bone must be covered or invested with enamel. This is effected by folds or projecting processes of the capsule or sac, which, hanging from above, intervene between the plates of bone, and there perform their peculiar secretion, depositing the enamel. But it would appear that these processes, becoming at length tightly embraced by the plates of enamel which they have themselves secreted, throw out a less perfect material, as it were; this is called the *crusta petrosa* or cement. When the tooth thus formed rises above the gum, and when attrition wears down a part of it, the interstices caused by the wasted processes of the septa of the sac are exposed, and the food is crammed down into these crevices, and then on making a section of the tooth we may discover four substances, ivory, enamel, crusta petrosa, and foreign matter, in alternate layers.

Now, contemplating the slow formation of the teeth whilst yet deep in the jaw,—their curious mode of growth, adapted to the form of the jaw,

—the articulation of the jaw with the head,—the position and powers of the muscles that are to move the jaw, with the means to be employed by the animal in gathering, masticating, and digesting its food,—we can desire no more absolute proof of prospective contrivance and design. Were we to seek further, we have only to compare these mechanical appliances with the instincts and propensities of the animals.

There is but one thing more worthy of attention in the teeth, than their mechanism, we mean their vital properties. Is it not a wonderful thing to see the jaw of the infant with a ridge upon its gums, harmless to the nipple; and then at the time when the powers of digestion vary, and become suited for stronger food, to find sharp teeth arise, a range of them having been provided, which when fully developed are in exact accordance with the size and form of the jaw of the child? Can any one tell us how these teeth should waste at an appointed time, to give place to others of stronger form and of larger dimensions conforming to the adult jaw-bone? The phosphate, carbonate, and fluate of lime, do not differ in these milk teeth, or deciduous teeth, and in the adult teeth; yet, by a secret process of decay, the first fall out in the period of childhood, and the second last a long lifetime.

XII.

OF THE MOUTH.

Our author has said that everything in the structure of the mouth is mechanical, and he has given a very attractive view of the varieties of the mechanism in the mouths and bills of animals. But so far from exhausting the subject, he has left some of the most interesting particulars untouched. In man, the mouth is not flat because he has hands, but because it is a part of that apparatus, which is the most curious and important of all the bodily structures,—the instrument of speech. In that light we shall presently take it up separately, not doubting that it will reward the reader's attention.

Let us, in the meantime, consider some of the common properties of the mouth; and first, of the most obvious parts, the lips. Nothing serves better to make us appreciate the blessings we enjoy, than examining the organization of a part which, from its familiarity, and the absolute perfection of its action, we neglect or think meanly of. The lips receive the food, and aid in mastication; they are a principal part of the organ of speech; they are expressive of emotion; they are the most acutely sensible to touch. But all this never moves our surprise or admiration.

If we know anything of muscularity, we must presume that there is a concourse of fine muscles converging to the lips and surrounding them. But what gives the lips their sensibility? This was a question early suggested to me in my investigations on the nerves; when experiment showed that one nerve went to the lips for sensation, and another for motion. The vermilion surfaces of the lips possess their exquisite sensibility through minute and delicate villi, into which the extremities of the sensitive nerve are distributed: and these, being covered only by a cuticle the most thin and transparent, afford the ready instrument of touch. We see how the child uses the lips, as giving him his first information of the qualities of bodies.

It is certainly an unexpected thing to find that two organizations totally distinct, combined in the lips, should be necessary to the simplest act. If the nerve of motion be cut and has lost its function, the animal puts its lips to the grains it feeds upon, but cannot gather them. If the nerve of sensation be injured, the animal presses its lips to the food, but wants the sensibility by which the motions of the lips should be directed. These facts show that whilst sensibility and motion are distinct faculties and depend upon different nerves, they are necessarily combined for so simple an act as taking the food into the mouth. We thus daily see that in paralysis, sometimes one property is lost, sometimes another; a circumstance most important to the physician.

As connected with our present subject, it is a strange thing to see that, whilst a person may have every capacity for motion in the lips and tongue, he will have the morsel remaining in the mouth without knowing it. The first instance I found of a defect in the lips exactly similar to that produced by cutting the nerve of sensation on one side of the face, was in a gentleman who, being under the hands of his dentist, had the nerve of sensation hurt by the pulling of a tooth: and having a glass of water given to him, remarked that the glass was a broken one: the fact being, that the portion of the tumbler in contact with one half of his lips was not felt at all, which gave him the same sensation as if a bit of the glass had been broken away.

We might show, in the lower creatures, an infinite variety in the forms of the mouth; but even in the mammalia, we may perceive that the lips are projected, and have a power almost like that of the hand. The horse has great power in his lips. The camel, the elk, but more especially the rhinoceros, have a still greater mobility, and the latter has a very fine sensibility in the hook-shaped extension of its upper lip: the snout of the tapir and the trunk of the elephant belong to the lips, rather than to the nostrils. We have the least equivocal proof of this, in their supply of nerves, which are only an enlargement or prolongation of those nerves which in man go to the lips. Nay, we may state a fact, perhaps unexpected to the reader, that the whiskers of animals of the cat tribe have entering into their roots branches of the same nerve which gives sensibility to the lips; and the palpa and tentacula in the lower classes of animals, as the crustacea and insects, however different these organs may appear, are known to belong to this order of parts, by the same proofs, their supply of nerves.

We might be tempted here to speak of the bills of birds, had they not already attracted the attention of our author. We shall, therefore, rather fortify his conclusions by attention to the structure of the tongue. The human tongue is, no doubt, the most admirable of all the organs. We might have very obvious proofs of intention and adaptation in the long rough tongue of the ox, or in the still more curious and active tongue of the camelopard, or in the tongue of the insectivorous animals, the bear, the chameleon, and anteater, or in the variety of curious instruments, darts or saws, sheathed in the bills of insectivorous birds. But we ourselves have an organ, however apparently simple, finer than all these. The human tongue, containing muscular fibres in every possible direction, and round, soft, and mobile, is less admirable as an organ of mastication, of taste, or touch, than as the organ of speech, modulating with every possible variety the sounds issuing from the windpipe. On the upper surface of what is termed the dorsum of the tongue, there are rough papillæ which in some measure correspond with what we see in animals: they are subservient to the taste. Some of them have a mushroom-like top, and a stalk projecting from the bottom of a little hollow, and there the sapid particles of the food lodge, and prolong the enjoyment of the palate. But in the organization of the tongue there is one minute point of structure more curious than all the rest. When the papillæ are examined with a magnifying glass, there are seen certain small bodies, consisting of a grey sheath, within which there is a little red point; and this point is capable of erection, thus projecting and becoming the organ of taste. It is so erected when the morsel is in the mouth, or when we are in the immediate anticipation of food. There are other more minute processes studding the surface of the tongue, and these contain the extremities of nerves which are sensible to touch. It must surely, therefore, be considered an admirable thing to find so many faculties seated here, each with its appropriate organization, and each most curiously connected with other structures—that we should have the power of mastication, of deglutition, of modulation of the voice, the senses of taste and of touch, concentrated in one apparently simple organ.

Not to speak of other relations, can there be any better proof of design, than the effects of the excited sensibility of the tongue? No sooner have these gustatory points of nerves been excited, than there is poured out into the mouth most abundantly, by four distinct tubes, the saliva, that fluid* which facilitates mastication, and directly prepares the food for the action of the stomach. And however well we might imagine such a supply of fluid to assist deglutition, this is not all that is here done in preparation; for whilst the morsel is moved by tongue, and lips,

* We presume that the fluid is chiefly useful in mastication, as the glands are large, and the fluid most abundant in animals that chew the cud. In all, these glands are so disposed as to receive gentle pressure from the motion of the jaw; so that, whilst their vascular apparatus is excited by the sensibilities of the tongue, the fluid is urged from the ducts by the pressure of the jaw and muscles which move it. The fluid itself is neither acid nor alkaline.

and jaws, an appropriate fluid is collecting in what appear to be mere irregularities in the back part of the throat, but which are, in truth, so many receptacles, that pointing towards the stomach, give out their contents as the morsel passes.

There is one curious circumstance which we may notice before quitting this subject. Eating seems always to be an act of the will, and attended with gratification. It is well known that the operation, or what is very nearly the same, may go on within the stomach, without any outward sign at least of pleasure. The gizzard (with which we are most familiar in fowls, though it be, in fact, found in the vegetable feeders of the different classes of animals) is correctly enough described as an organ of mastication, in which there is an incessant and alternate action of opponent muscles, as in the motions of the jaws. In the stomach of the lobster we have not merely the muscles of mastication, but the teeth also: so that it appears the function may be performed altogether internally, and without the volition, and probably without the sensations, that accompany the offices of the mouth. We mention this, as drawing the reader to comprehend that many organs may be in operation in the internal economy, without our consciousness.

Our author, with much propriety, from time to time, adverts to those changes in the organization which accommodate the animal to new conditions. Now, in terrestrial animals, the act of swallowing must be accommodated to the atmosphere; but if the animal lives in water, and still breathes the air, the structure of the parts must be changed. The crocodile seizes its prey, and descends into the water with it. Its power of descending does not, as in the fish, result from compressing the air-bladder: but is owing, as we have shown, to a provision in its ribs and lungs. Unless the crocodile could expel the air from its lungs in a greater degree than the mammalia are capable of doing, it could not crawl upon the bottom, nor retain its place there without continual exertion. There is an adaptation to this mode of destroying its prey, by carrying it under water, in the mouth, as well as in the thorax and lungs. The crocodile has no lips; it lies on the shore basking with its mouth open, and flies light upon and crawl into its mouth. Against these the air tubes are protected, not by the lips and sensibility of the mouth, but by an apparatus which separates the mouth from the throat and windpipe. This partition, between the cavities is necessary when the animal seizes its prey: for as it plunges under the water with open mouth, the air tube must be protected against the ingress of the water. For this purpose, there is a transverse ridge, arising from the body of the bone of the tongue, which raises a duplicature of the membrane so as to form a septum across the back part of the mouth; whilst the curtain of the soft palate hanging from above meets the margin of the lower septum, and they form together a complete partition between the anterior and posterior cavities. Thus the animal is enabled to hold its prey in the open mouth, without admitting the water to the air passages.

With these observations, we hope the reader will return to peruse, with increased interest, the conclusions so well stated by our author, vol. i., p. 223.

XIII.

OF HUNGER AND THIRST.

For very sufficient reasons, we have preferred taking the illustrations of design from the mechanical structure of the body. We may now introduce some instances from the living properties, the propensities and appetites.

Hunger and thirst are in truth senses, although the seat or organ is not easily ascertained. The wants, and desires, and pain accompanying them resemble no other sensations. Like the senses, they are given us as monitors and safeguards, at the same time that, like them, they are sources of gratification.

Hunger is defined to be a peculiar sensation experienced in the stomach from a deficiency of food. Such a definition does not greatly differ from the notions of those who referred the sense of hunger to the mechanical action of the surfaces of the stomach upon each other, or to a threatening of chemical action of the gastric juice on the stomach itself. But an empty stomach does not cause hunger. On the contrary, the time when the meal has passed the stomach is the best suited for exercise, and when there is the greatest alacrity of spirits. The beast of prey feeds at long intervals; the snake and other cold-blooded animals take food after intervals of days or weeks. A horse, on the contrary, is always feeding. His stomach, at most, contains about four gallons, yet throw before him a truss of tares or lucerne, and he will eat continually. The emptying of the stomach cannot therefore be the cause of hunger.

The natural appetite is a sensation related to the general condition of the system, and not simply referable to the state of the stomach; neither to its action, nor its emptiness, nor the acidity of its contents; nor in a starved creature will a full stomach satisfy the desire of food. Under the same impulse which makes us swallow, the ruminating animal draws the morsel from its own stomach.

Hunger is well illustrated by thirst. Suppose we take the definition of thirst—that it is a sense of dryness and constriction in the back part of the mouth and fauces; the moistening of these parts will not allay thirst after much fatigue or during fever. In making a long speech, if a man's mouth is parched, and the dryness is merely from speaking, it will be relieved by moistening, but if it comes from the feverish anxiety and excitement attending a public exhibition, his thirst will not be so removed. The question, as it regards thirst, was brought to a demonstration by the following circumstance. A man having a wound low down in his throat, was tortured with thirst; but no quantity of fluid passing through his mouth and gullet, and escaping by the wound, was found in any degree to quench his thirst.

Thirst, then, like hunger, has relation to the general condition of the animal system—to the necessity for fluid in the circulation. For this reason, a man dying from loss of blood suffers under intolerable thirst. In both thirst and hunger, the supply is obtained through the gratification of an appetite; and as to these appetites, it will be acknowledged that the pleasures resulting from them far exceed the pains. They gently solicit for the wants of the body: they are the perpetual motive and spring to action.

Breathing, as we have seen, is even more directly necessary to life than food; but to this we are differently admonished. An appetite implies intervals of satiety and indifference. The uninterrupted action of breathing could not be supported by a perpetual desire; we cannot imagine such a uniformity of sensation. The action of breathing has been made instinctive, while pain and the alarm of death are brought as the only adequate agents to control the irregularities of a function so necessary to life. Pain does here what desire and the solicitation of pleasure could not accomplish.

XIV.

THE STOMACH OF THE HORSE.

When we think of the adaptations of animal structure to the different conditions of living creatures, the camel, the ship of the desert, immediately occurs; and no doubt it is highly interesting to observe how this animal is adapted to the sandy waste, in its eye, its nostril, its foot, the cells of its stomach, and its capacity of endurance. But it is, perhaps, more to our purpose to look to our domestic animals, and the most of all deserving attention is the horse.

Of all creatures, the horse has the smallest stomach relatively to its size. Had he the quadruple ruminating stomach of the ox, he would not have been at all times ready for exertion: the traveller could not have baited his steed and resumed his journey. The stomach of the horse is not so capacious, even when distended, as to impede his wind and speed; and the food is passing onward with a greater degree of regularity than in any other animal. A proof of this is, that the horse has no gall-bladder. Most people understand that bile is necessary to digestion; and the gall-bladder is a receptacle for that bile.

Where the digestive process is performed in a large stomach, and the food descends in larger quantities, and at long intervals, the gall-bladder is necessary; and there is that sympathy between the stomach and gall-bladder, that they are filled and emptied at the same time. The absence of the gall-bladder in the horse; therefore, implies the almost continual process of digestion; which again results from the smallness of the stomach.

Another peculiarity in the horse is the supply of fluid. When the camel drinks, the water is deposited in cells connected with the stomach; but if a horse drinks a pail of water, in eight minutes none of that water is in the stomach; it is rapidly passed off into the large intestine and the cæcum. We cannot resist the conviction that this variation in the condition of the digestive organs of the horse, is in correspondence with his whole form and properties, which are for sudden and powerful, as well as long-continued exertion.

XV.

OF THE GIZZARD.

THE gizzard is a favourite illustration with our author; he takes it up in Chaps. x. xii. xv. xvi., as the example of compensation, relation, &c.

The bill of a bird has extensive relations both externally and internally. When we see a bird trimming his feathers with his bill, and combing out each feather from the root to the point, we cannot but observe, that admirably as feathers are formed for flight and for protection against cold and wet, they would be inconsistent with the tongue and teeth of the quadruped. The rough tongue would not penetrate to their interstices; nor would the ruder operation of the dog's teeth suit the delicate texture of the quills. The bill, therefore, implies the absence of teeth and of salivary glands. Lips and muscular cheeks are necessary for mastication; and however familiar the operation may be, a chapter might be well occupied to show how cheeks and lips, salivary glands and teeth, must co-operate before a morsel can be swallowed*, and how the

* See a paper on this subject, in treating of the nerves of mastication, in 'Phil. Trans.' for 1829.

derangement of one filament of the nerves supplying these parts disorders the whole train of actions. We have to show, then, how this function, deficient in the bird, is compensated by internal structure.

The gizzard is a fleshy stomach, the exact substitute for the muscles of the jaws, and teeth. Its substance consists of a strong muscle; the dark part of the gizzard being the muscle, and the shining part of it the tendon to which the muscular fibres are attached. There are, in fact, two muscles with a central tendon; it is what anatomists call a digastric or double-bellied muscle. The cavity within this muscle is lined with a dense, rough, insensible coat, and there are always to be found contained in it small stones, generally of quartz, if it be within the reach of the creature's instinct to obtain them. The grains are mixed with these portions of stone; and if we put our ear close to a bird, we shall hear the grinding motions going on as distinctly as the noise of the horse's jaws in the manger. In fact, this digastric muscle or gizzard is equivalent to the muscles of the jaws, and the pebbles are a fair equivalent to the teeth, with this advantage, that when they are ground down, the instinct of the bird supplies it with more. It picks up some small portions of gravel with as much alacrity as it will the grain itself. Some have supposed that this was sheer stupidity in the fowl; but here surely instinct is better than reason.

When we recollect the provisions against attrition necessary to make the teeth last for the full period of the life of a graminivorous quadruped, we are prepared to understand the advantage of this beautiful and simple substitute, which, to so small a creature as a pigeon, gives an equal power over the material of its food, as the horse has with its powerful jaws, and strong grinding teeth.

However, we are but describing a new instrument for grinding, or comminuting the food: yet this alone is not sufficient to supply what was wanting in the mouth; and in passing, we may observe that the gizzard does not exclusively belong to birds. The gillaroo trout and the mullet have gizzards. The toothless ant-eater has a gizzard: it lives on scaly and hard insects, such as beetles; and to assist in bruising them in its muscular stomach, it picks up pebbles like the domestic fowl.

Before the grain descends into this grinding apparatus of the bird, it is deposited in the crop; from the crop it descends, by little and little, into the cardiac cavity, as the first part of the stomach is called. In this latter cavity there are glands which secrete the gastric juice, and which fluid is necessary to digestion. We should here also note a particular provision in the upper orifice of the gizzard, namely, the overlapping of a part of the muscle, which produces an obliquity in the passage, and holds the contents of the stomach confined during the strong action of grinding. It was indeed at one time supposed that such a mechanical operation of the stomach as we have described in the gizzard, fitted the food to supply the nourishment of the body; but, we repeat, that it has no further operation than that of comminuting the hard food, and preparing it for the action of this animal fluid, the gastric juice, which digests; and digestion is the first process of assimilation.

It may be interesting to the reader to know that the lower orifice of the gizzard, where it opens into the first intestine (*duodenum*), is differently guarded in different families of birds. In birds which have abundance of food, the gizzard has no valve to retard its escape; so that a greater part of the grains or seeds on which they feed passes off undigested; a fact which we touched upon elsewhere. Were birds of prey furnished with the same grinding apparatus which is suited for birds that feed upon grain, our argument would be overturned. But in them the gizzard is very weak; the cuticular lining of the stomach very thin; and the gastric glands, which pour out the digesting fluid, very large. In the hawk and kite we find no such macerating crop as in the domestic fowl.

Our author states that one class of birds cannot digest grains; the other cannot digest flesh. This, however, taken literally, does not accord with the experiments of Mr. Hunter, since he brought the carnivorous birds to live on grains, and the granivorous fowls to live on meat. But the necessity of accomplishing this change by very slow degrees leaves the substance of our author's argument sustained.

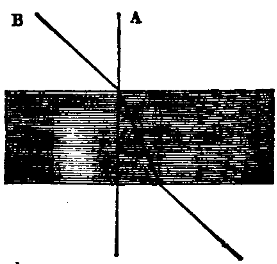
It is presumable that animal and vegetable matter are, in their ultimate elements, nearly the same; and, therefore, the last action of assimilation of the food is probably similar in all creatures. The variety of organization or structure in the stomach will be found to depend on the proportion of nutritious matter in the mass that is swallowed. A vegetable feeder requires, from the poverty of its food, to be continually digesting; and happily its food is in abundance around it. The carnivorous animal gorges its food, after long and irregular intervals; its prey is precarious; but then that food is richer in nutritious matter, and requiring to undergo only the last process of assimilation. The variety and complication in the structure of the digestive organs depending on the nature of the food, is not only exhibited in quadrupeds and birds, but in fishes and in insects. Insects that suck blood have a simple canal: the grasshopper and white ant, vegetable feeders, have a complicated canal. Just for the same reason the intestines of the lion are short and wide, and those of the goat long and complicated.

XVI.

ON THE RAYS OF LIGHT, THEIR REFRACTION AND REFLECTION.

The nature of light has ever been a subject of controversy. It was Newton's explanation that luminous objects give out particles of inconceivable minuteness, and moving with extreme velocity. "What mere assertion," says Sir John Herschel, "will make any man believe that, in one second of time, in one beat of the pendulum of the clock, a ray of light travels over 192,000 miles; and would therefore perform the tour of the world in less time than a swift runner would make one stride?" In short, there is nothing like it but the influence of attraction; which is so instantaneous as to admit of no calculation of time at all.

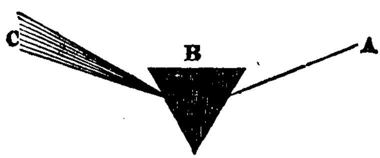
A different theory from that of Newton was suggested by Huyghens, who supposed a highly-elastic fluid to fill all space, and which, when moved, produced the effects ascribed to light. Instead of minute particles diverging from the luminous body, he substituted waves or vibrations, propagated through this elastic ether. The late Dr. Young, and some continental philosophers more recently, took up this hypothesis and supported it by ingenious experiments. But notwithstanding that it is the favourite theory of the day, difficulties appear still to encumber it. The theory of undulations implies the advance and recoil of the elastic medium, and that gives the idea of retardation. The supposition of light being the effect of the motion of an ether, does not fall in with our conceptions of the manner in which it enters into the composition of bodies, or influences chemical combinations, or affects the living powers of animals and vegetables. The merits of the two theories, however, need not be discussed here. It will be sufficient for our purpose to represent a beam of light by a line drawn with the pen, and to enter on the explanation of a few of the laws which influence it in passing through transparent media.



When the ray of light, as A, passes perpendicularly from a rarer into a denser medium, as from air into water, it suffers no change in its direction; but when it passes obliquely, as B, it takes a new direction towards the perpendicular, making a sudden angle, as if broken,—and this is refraction. Two circumstances, therefore, influence the ray of light;—the angle at which it falls, and the density of the body into which it passes. When the ray B passes from the denser medium into the rarer, it is again refracted, but away from the perpendicular, and takes its original course, provided the surface at which it goes out is parallel to the surface at which it entered.

When a ray strikes upon a body that is not transparent, or only imperfectly so, it is in part reflected, that is, struck off again, bent back, or reflected, and enters the eye, conveying to us the impression of the form and colour of that object.

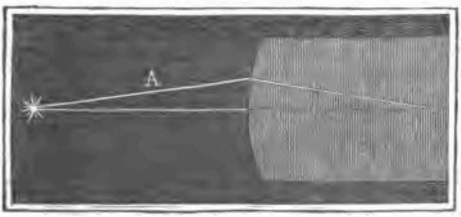
But the expression which we have used requires explanation; for how is it that the reflected rays should convey the idea of colour?



The prism is a piece of glass so formed that the rays must fall obliquely on one or both of the surfaces, and suffer refraction. Thus the ray A striking into the prism B is refracted; but all its parts are not equally refracted, and as the light consists of parts differing in colours, and which are differently refracted, it is divided or dissected into several colours, called the prismatic colours. The spectrum, as it is termed, thus formed, consists of seven colours; that which is least refracted being red, and in succession orange, yellow, green, blue, indigo, and violet. If these rays be re-compounded by passing through a convex lens, which, owing to the obliquity with which they fall, draws them to a point, the focus of the light will be again colourless. Some modern philosophers have reduced these prismatic colours of Newton to three primary colours, red, yellow, and blue; contriving, by the super-position of these, to produce the seven tints; while others have, on considerations not easy to be disproved, held that there is not any definite number of colours, but a gradation of tints from the extreme red to the extreme violet.

We may now understand the reason of the colour of objects. When light strikes upon a body, even upon the most transparent, part penetrates, part is reflected, and some part is lost. A dye is a disposition given to the surface of cloth to repel some of the rays of light more than the others; and the colour will be according to the ray, or the combination of rays, thus cast back and sent into the eye.

And here it is natural to reflect on the variety and beauty everywhere bestowed through this property of the beam of light. What a dulness would have pervaded the surface of the earth if there had been only a white light! The beauties of the garden and of the landscape would have been lost to us. How is the beauty of the latter enhanced by the almost infinite variety of colour; yet still within that range which is agreeable and soothing to the eye, as well as consonant to our feelings! The human countenance, too, although capable of exciting our warmest sympathies by form and motion alone, has that beauty perfected by colour, varying under the influence of emotion.



It remains, in order that we may apply these facts to the explanation of the structure of the eye, to show how the rays proceeding from a body and falling upon a convex glass suffer refraction. The ray that strikes upon the centre, being perpendicular to the glass, passes on undeviatingly. But each ray as it strikes a point removed from the centre, must impinge with more obliquity, in consequence of the curved surface; and as the refraction of all the rays will be in proportion to the obliquity of their incidence, they will converge towards the central direct ray. Thus A, as it passes through the glass, suffers refraction towards the perpendicular line, in proportion as it deviated from it, on passing out of the air into the glass. These few simple statements may suffice for understanding the comparison which we are now to make between the eye and optical instruments.

XVII.

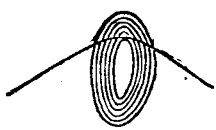
THE EYE COMPARED WITH OPTICAL INSTRUMENTS.

We have elsewhere expressed our surprise that the structure of an animal body should so seldom be taken as a model. In the history of inventions, it appears quite extraordinary that the telescope and the microscope should be modern, when, as it should seem, the fine transparent convexity of the eye might have given rise to imitation, as soon as man learned to give shape to natural or artificial glass. It reminds us of the observation of Locke, in speaking of a discovery, that it proved the world to be of no great antiquity. Yet we must estimate the invention of the telescope and microscope as by far the most important in their consequences of either ancient or modern discoveries. The first opens to us an unlimited expanse, not only of new worlds, but systems of worlds, and new laws evinced in the forces which propel and attract these; since in the heavenly bodies we find no material contact, nor pressure, nor impulse, nor transfer of power—nor effect of heat, nor expansion of gases—nothing, in short, which can be illustrated by mechanism. By the microscope, we contemplate the minute structure of animals and things but for its aid invisible: the balance of the cohesive and repulsive forces as they order the changes in the material of the world, and in that of our own frames. Yet these instruments are not in contrast with the eye: but through the comparison of them we discover the wonderful adaptations of that organ; of which it has long ago been said, that it can at one time extend our contemplations to the heavenly bodies and their revolutions, and at another limit its exercise to things at hand, to the sympathies and affections of our nature visible in the countenance.

If we put aside the consideration of the living properties of the organ, as the extraordinary variety and degrees of sensibility in the nerve of vision, and confine ourselves to points easily comprehended, as, for example, the mechanism of the eye, and the laws of optics as applicable to the humours, we shall find enough to admire.

When we look upon the optician's lens, however perfect its polish may be, we can see its convex surface: that is to say, the rays of light which strike upon that surface do not all penetrate it, but are in part reflected to our eye, which is the occasion of our seeing it. We do not see the surface of the cornea of the human eye. Here, then, is an obvious superiority, since it implies that all the rays of light which strike the cornea enter it and are refracted, and none are returned to our eye. If we take the optician's lens between our fingers and hold it under water, we can no longer see it, however transparent the water. The reason of this is, that the rays of light are reflected when entering from a rare medium into a denser, more abundantly in proportion to the difference of the density. When the ray of light has penetrated the water, it also penetrates the glass, because there is not that difference of density between the water and the glass which there is between the atmosphere and the glass. From this we may estimate the importance of the surface of the cornea being moistened by the tears; for however thinly the water may be spread over the surface of the eye, it is sufficient to make those rays that would otherwise be reflected penetrate the cornea.

The whole humours of the eye are constituted with a regard to this law. There is nowhere an abrupt transition from a rare to a dense humour. The ray is transmitted from the cornea into the aqueous humour, and through that humour into the lens or crystalline humour. Were this latter humour uniform and of the density of its central part throughout, the ray would be in part reflected back from its surface. But it is not uniform, like a mass of glass: it consists of concentric layers increasing in density from the surface to the centre. If we first look at the entire lens, and then take off its concentric layers, we shall see the surface of the internal nucleus more distinctly than the exterior and natural surface. The reason is obvious: the nucleus is so much more dense than the atmosphere, that the reflection of the rays from it is more abundant. We now comprehend how finely it is provided that the crystalline lens should be surrounded with the *liquor Morgagni,* a fluid which is but in a slight degree more dense than the aqueous humour. The exterior surface of the lens itself is only a little more dense than the surrounding fluid, and each successive layer, from the surface to the centre, is of gradually increasing density: so that if we were to describe the course of the ray, it would not, as we see in the ordinary diagrams, pass like a straight line of



the pen, but in a curved line, showing the gradual manner in which the ray is refracted through successive transparent layers. As it enters in the anterior half of its passage, it encounters media of increasing density: but as it passes out behind, it is transmitted through media diminishing in density. The ray is nowhere opposed by that sudden increase of density which gives a disposition to reflection; and it passes through the vitreous humour still refracted, the density of that humour having a just correspondence with the posterior surface of the lens. In the atmosphere there is a similar arrangement for receiving the light proceeding from the sun or stars: for as the density of the air diminishes as the height above the earth increases, the surface of our atmosphere, from its rarity, must almost resemble free space; consequently the light falling into it will penetrate more abundantly than if the air were compressed as it is near the earth, and were of uniform density. We thus see the obvious superiority in the structure of the eye to any thing that can be composed of glass, which is of uniform density throughout, and must therefore present a succession of surfaces where rare and dense media are abruptly opposed to the rays transmitted.

We may observe another happy result from the peculiar structure of the lens. A magnifying glass is never true: an aberration of the rays takes place in the pencil of light, as the rays are drawn to a focus. The rays which penetrate near the centre are projected so as to be drawn to their focus beyond those rays which pierce through nearer the edge. The rays penetrating the centre of this double convex glass will project the image to A, whilst those penetrating nearer the circumference, and consequently falling more obliquely, will form a focus nearer the lens at B. But in the crystalline humour of the eye, which corresponds with the optician's lens, the exterior layer having less density, and therefore a diminished property of refracting the ray, the image is carried farther off to A; and by this means it is ordered that wherever the ray penetrates, it shall be drawn to an accurate focus.

Some modern philsophers have asserted that the eye is not perfectly achromatic in every adjustment. The term implies the property of the instrument to represent an image divested of the prismatic colours; those false colours which attend the refraction of the rays of light. If the statement be correct, it is nothing against our argument; nor have those inquirers advanced it with any such view*. We know that in all the ordi-

* Professor Blair (*Edinburgh Transactions*, iii.) expressly derives an argument in favour of design from this statement of his opinion, and his objection to Boscovich.

nary exercises of the eye the image is perfect, having neither penumbra nor prismatic colours. This property of the eye results from the different media through which the rays are transmitted, and the gradual transmission which we have just mentioned. Dollond's achromatic glasses, a great improvement upon the telescope, were made on this principle. He composed the object-glass of the telescope of crown-glass and flint-glass, so that while, by the combined effect of their convexities, they drew the rays to a focus, the dispersive power of the one was counteracted by that of the other.

Let us endeavour to explain this. A, a beam of light, being composed of the different coloured rays, passes through the prism B. (See Fig. p. 309.) Instead of passing onward in a straight line, it is refracted to C in distinct, and, consequently, coloured rays. Whilst the whole of them are bent or refracted at an angle from the dotted line, they are also diverging from one another. Their deviation from the straight line is their *refraction:* their diverging from each other is their *dispersion.* These properties being distinct, it is conceivable that glass of a different chemical composition may affect the one to a greater degree than the other, and, therefore, that a lens may be composed of different kinds of glass (crown-glass and flint-glass, for example), so that the convergence of the rays into a focus may be obtained without the dispersion of the rays, and the consequent production of false colours round the image. This is what Dollond nearly accomplished, and upon these principles. That the effect of this very artificial arrangement is attained in the eye is a remarkable proof of the perfection of its adaptation to the properties of light.

The last circumstance which we may mention in continuing the comparison, is the drawing out of the tube in the telescope to accommodate the foci of the glasses to the distance of the object. It is sufficient to say that the eye possesses this property of accommodation. That we do not understand how the operation is performed, only strengthens the argument in favour of the perfection of the eye: since the power exists, and is exercised with an ease which hardly permits us to be sensible of it.

XVIII.

OF THE MEANS BY WHICH THE EYE IS PROTECTED.

When an astronomer, in the darkness of night, and shaded from the light of his chamber, moves his telescope from star to star, his eye is accommodated to faint impressions; that is, the sensibility of the retina is then accumulated, so that when he directs his instrument to the brighter objects his sensation is painful. And if, at another time, he should be observing the sun, without having guarded the eye by smoking the glasses, or by some other means diminishing their transparency—the stroke upon the retina will not only be painful, but may prove destructive to its fine texture, and occasion a defect of vision which will continue through life. If the apparatus in the tympanum of the ear be destroyed, and the defect supplied by an ear-trumpet, the person will be startled by those who speak into this trumpet: for if they are not in the habit of pitching their voices distinctly and softly, the sound will jar painfully upon his ear. By these considerations, we are prepared to contemplate that beautiful provision by which the natural eye is protected against the sudden intrusion of light, or the too intense illumination of the object upon which it is directed.

The iris is a curtain, or septum, which stretches across the aqueous humour, and is anterior to the crystalline lens: it is perforated in the centre, and that perforation is the pupil—the black central spot which we see when we look into the eye—black, for the reason which we have assigned, that the rays piercing there are not returned, and the absence of rays is blackness. But the rays strike the anterior part of the iris itself round the perforation, and they are partially, at least, reflected, giving the colour to the eye—grey, or blue, or hazel.

Perhaps the diagram (vol. i., pp. 28, 29) will explain the structure of the iris and pupil; and show the mode in which the pencil of rays is enlarged or diminished, and the intensity of the image in the eye thus made greater or less in proportion to the illumination.

The iris, then, we understand to be a muscular septum or partition, with two sets of fibres; a straight set converging to that margin of the iris which forms the pupil, and a circular set running round the exterior margin of the iris. At page 290 of vol. i. we have given a representation of the iris of the lion. The pupil or open space is oval in this animal; B B are the straight fibres converging to the exterior margin of the iris; and C C are the circular fibres of the margin. These two sets of fibres act against each other, and in a moderate light the pupil is moderately expanded: but when the light is obscure the circular fibres relax, and the straight fibres act; the iris is then diminished in diameter, and the pupil enlarged. The contrary takes place when too intense a light strikes into the eye.

This guardian action of the iris is more rapid than words, and as quick as thought; and it is to be remarked that this apparatus is animated by nerves which go back to the sensorium: so that the impression must be received in the sensorium before the iris can be directed in its motions.

Such, then, is the apparatus by which the nerve of vision is guarded; and as marking its necessity, let us remember that the retina is susceptible, in an extraordinary degree, of various impressions of light: that it will be sensible to an object illuminated as one, and as thirty thousand. It is obvious, that either we must have groped in the dark during the evening or moonlight, or have been quite dazzled and overpowered by the brightness of the sun, had not this fine mechanical apparatus of the iris been adapted and assigned for the protection of the nerve.

But the nerve is protected in another way, or rather, we should say, the force of the impression is regulated. We have seen that the colours of objects are owing to the rays of light being reflected from them; that on a surface perfectly black the rays sink in and are lost, and we recognize the object only by its outline being contrasted with surrounding coloured bodies, not by the light reflected from itself. When the eye of an animal is destined for the bright light of day, a black pigment is behind the nerve, and the nerve itself being transparent, the ray is transmitted and lost. But if it be required that the eye shall be suited to the habits of an animal that prowls by night, then there is combined with the large eye and the very dilatable pupil, calculated to receive a great pencil of rays, a property of reflection in the *tapetum* or carpet, that is, the surface at the bottom of the eye on which the nerve is expanded. Instead of the black and absorbing pigment, there is a secretion furnished by that surface, which, like a dye, throws off or reflects the light, or reflects it back like the silver on the back of a mirror. This gives a second impulse to the nerve, and has the effect of doubling the force of the impression.

Let us now see how an organ of the extreme transparency and delicacy of the eye is guarded from injuries of another kind.

And, first, we may observe the combination of the living properties with the motion and mechanism of the eye-ball; how the extreme delicacy of the surfaces of the eye has adapted to it the fine sensibility seated in the eye-lids and roots of the eye-lashes. The pain excited by the smallest particle that floats in the atmosphere would be the source of constant suffering, were there not connected with and animated by the same sensibility an apparatus, mechanical and hydraulic, for the obvious purpose of ridding the delicate surface of the eye of all foreign matter.

Can there be anything more interesting than to find the whole of this apparatus under the guidance of a property different from that of consciousness and volition?

I have seen many instances of persons deprived of the sensibility of the surfaces of the eye from the affection of one nerve alone, without the loss of vision, or of the motions of the eyelids, or of the flow of tears; but it has been impossible in such persons to preserve the organ, by assuring them of the necessity of these motions, either through the direct action of the eye-lids, or by the aid of their fingers. The eye's surfaces, being deprived of sensation, are no longer regularly moistened: soot and dust rest upon them; and although they are insensible they inflame; the transparent cornea becomes opaque, and the eye is lost. This is the consequence neither of the want of sensibility in the retina, nor of the capacity of motion in the eye-ball and eye-lids being lost, nor of failure of the spring of water that runs continually over the eye: it results simply from a loss of that relation in the sensibilities suited to the materials and influences around us, and the protecting motions which they excite. It at once answers the querist who asks, why we suffer pain? We reply to him by another question. How are we to hear or see, or how enjoy the sense from impressions so delicate as those of sound and light; or enjoying these, by instruments so exquisitely framed, how are these instruments to be protected from the ruder shocks to which they must be exposed? These considerations lead to the conclusion that if he object to one part of the system, he objects to the whole of that by which we hold our present existence.

The motions of the eye and eye-lids, which are directed by this sensibility, must be performed with extreme rapidity. To rinse anything in water, or to rid it of dust by shaking it in the wind, the action must be quick; and such a motion is possessed by the eye of the fish, although the eye-lids and lachrymal apparatus are in them unnecessary.

If we are giving proofs of design, we can have none more obvious than that suggested in the Preliminary Discourse, in the eye of the mud crab, an animal which, like the eel, seeks its food in mud and turbid water. Emerging from such a bed, its eye is covered with slime, and would be useless: but to provide against this inconvenience there is a little brush near the eye, to which the prominent horny eye can be raised, and against which it is wiped, with an action as intelligible as that of a man wiping his spectacles. The cray-fish, too, which burrows in the banks of rivers, has the same provision, although the structure is less perfect.

I have assumed that the action of the eye of fishes is rapid. I must confess that I have not seen this, but we are entitled to conclude that they possess the motion, as fishes have other muscles besides those necessary to direct the eye; muscles which, by the oblique direction of their fibres, are calculated to give extraordinary rapidity of motion, and resemble that apparatus which gives the rapid instinctive motions to our own eye.

The first time that we observe any remarkable phenomena, they excite more emotion, and we describe them with more interest. I shall therefore extract here a portion of a paper given to the Royal Society on the nerves of the eye, which it was necessary to preface by observations on the actions of the muscles, a subject which I conceived had not been fully understood.

XIX.

MOTIONS OF THE EYE-BALL AND EYE-LIDS.

We shall consider the muscles of the eye, first, as necessary to its preservation; secondly, as necessary to it as the organ of sense. We do not reflect on those actions of our frame which are most admirable in themselves, which minister continually to our necessities, and perfect the exercise of our organs, until we are deprived of them: like unnatural children, unconscious or unmindful of indulgence, we feel only the loss of benefits. "With much compassion," says the religious philosopher, "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 those two little muscles that serve to lift up the eye-lids, and so had almost lost the use of his sight, being forced, as long as this defect lasted, to shove up his eye-lids with his own hands." I have often thought of this saying when I have seen a patient in all respects in health, but without the power of raising the eye-lids.

There is a motion of the eye-ball, which, from its rapidity, has escaped observation. In the instant that the eye-lids are closed, the eye-ball makes a movement which raises the cornea under the upper eye-lid.

If we fix one eye upon an object, and close the other eye with the finger, so as to feel the convexity of the cornea through the eye-lid, we shall perceive when we shut the eye that is open, that the cornea of the other eye is instantly elevated; and that it thus rises and falls in sympathy with the eye that is closed and opened. This change of the position of the eye-ball takes place during the most rapid winking motions of the eye-lids. When a dog was deprived of the power of closing the eye-lids of one eye by cutting across the nerve of the eye-lids, the eye did not cease to turn up when he was threatened, and when he winked with the eye-lids of the other side.

Nearly the same thing I observed in a girl whose eye-lids were attached to the surrounding skin, owing to a burn; for the fore part of the eye-ball being completely uncovered, when she would have winked, instead of the eye-lids descending, the eye-balls were turned up, and the cornea was moistened by coming in contact with the mouths of the lachrymal ducts.

The purpose of this rapid insensible motion of the eye-ball will be understood by observing the form of the eye-lids and the place of the lachrymal gland. The margins of the eye-lids are flat, and when they meet, they touch only at their outer edges, so that when closed there is a gutter left between them and the cornea. If the eye-ball were to remain without motion, the margins of the eye-lids would meet in such a manner on the surface of the cornea, that a certain portion would be left untouched, and the eye would have no power of clearing off what obscured the vision, at that principal part of the lucid cornea which is in the very axis of the eye; and if the tears flowed they would be left accumulated on the centre of the cornea, and winking, instead of clearing the eye, would suffuse it. To avoid these effects, and to sweep and clear the surface of the cornea, at the same time that the eye-lids are closed, the eye-ball revolves, and the cornea is rapidly elevated under the eye-lid.

Another effect of this motion of the eye-ball is to procure the discharge from the lachrymal ducts; for by the simultaneous ascent of the cornea, and descent of the upper eye-lid, the membrane on which the ducts open is stretched, and then the tears flow unimpeded.

By this simultaneous motion, also, the descent of the eye-lid and the ascent of the cornea, the rapidity with which the eye escapes from injury, is increased. Even creatures which have imperfect eye-lids, as fishes, by possessing this rapid revolving motion of the eye, avoid injury and clear off impurities.

I may observe, in passing, that there is a provision for the protection of the eye, in the manner in which the eye-lids close, which has not been noticed. While the upper eye-lid falls, the lower eye-lid is moved towards the nose. This is a part of that curious provision for collecting offensive particles towards the inner corner of the eye. If the edges of the eye-lids be marked with black spots, it will be seen that when the eye-lids are opened and closed, the spot on the upper eye-lid descends and rises perpendicularly, while the spot on the lower eye-lid will play horizontally like a shuttle.

To comprehend these actions of the muscles of the eye, we must remember that the caruncle and membrane called *semilunaris*, seated in the inner corner of the eye, are for ridding the eye of extraneous matter, and are, in fact, for the same purpose as that apparatus which is more perfect in beasts and birds. The tears are imbibed by the *puncta* or orifices, which may be seen in the inner corner of the eye; and a tube, formed on the principle of a siphon, carries them into the nose: whilst the dust, washed to this corner, is thrown out by the apparatus which we have described.

The course of our inquiry makes some notice of these parts necessary.

In quadrupeds there is a gland for secreting a glutinous and adhesive fluid, seated on the side of the orbit next the nose: it is quite distinct from the lachrymal gland; it is squeezed by an apparatus of muscles, and the fluid exudes upon the surface of the third eye-lid. This third eye-lid is a very peculiar part of the apparatus of protection. It is a thin cartilage, the posterior part of which is attached to an elastic body. This body is lodged in a division or depression of the orbit on the side towards the nose. When the eye is excited, the eye-ball is made to press on the elastic body against the side of the orbit and force it out of its recess or socket; the consequence of which is the protrusion of the cartilaginous third eye-lid, or *haw,* as it is termed in the horse. By this mechanism the third eye-lid is made to sweep rapidly over the surface of the cornea, and, by means of the glutinous fluid with which its surface is bedewed, it attaches to itself and clears away offensive particles.

In birds, the eye is an exquisitely fine organ, and still more curiously, we might be tempted to say artificially, protected. The third eye-lid is more perfect than that of quadrupeds: it is membranous and broad, and is drawn over the surface of the eye by means of two muscles attached to the back part of the eye-ball, one of which acts by a long round tendon, that makes a course of nearly three parts of the circumference of the ball *. The lachrymal gland is small, and seated low, but the mucous gland is of great size, and placed in a cavity deep and large, and on the inside of the orbit. As the third eye-lid is moved by an apparatus which cannot squeeze the mucous gland at the same time that the eye-lid is moved, as in quadrupeds, the oblique muscles are particularly provided to draw the eye-ball against the gland, and to force out the mucus on the surface of the third eye-lid. It flows very copiously; and this is probably the reason of the smallness of the proper lachrymal gland which lies on the opposite side of the orbit.

We already see two objects attained through the motion of these parts: the moistening of the eye with the clear fluid of the lachrymal gland, and the extraction or protrusion of offensive particles.

There is another part of this subject no less curious: the different conditions of the eye during the waking and sleeping state. If we approach a person in disturbed sleep when the eye-lids are a little apart, we shall not see the pupil or the dark part of the eye, as we should were he awake, for the cornea is turned upwards under the upper eye-lid. If a person be fainting,

* See p. 47, vol. i.

as insensibility comes over him the eyes cease to have speculation; they want direction, and are vacant, and presently the white part of the eye is disclosed by the revolving of the eye-ball upwards. Look to a blind beggar; those white balls are not turned up in the fervour of entreaty; it is the natural state of the eye-balls, which are totally blind, and from the exercise of which the individual has withdrawn his attention. So it is on the approach of death; for, although the eye-lids be open, the pupils are in part hid, being turned up with a seeming agony, which however is the mark of increasing insensibility. These motions of the eye for the protection of the organ do not interfere with vision; they are performed unconsciously, and so rapidly that the impression of the object on the retina has not time to vanish in the interval. The motions of the eye-ball for directing the eye to objects are strictly voluntary, and are always connected with the exercise of the sense of vision.

It will now be admitted that the variety of the motions of the eye requires the complication of muscles which we find in the orbit, and unless the various offices and different conditions of the eye be considered, it will be in vain to attempt an accurate classification of the muscles or nerves of the orbit.

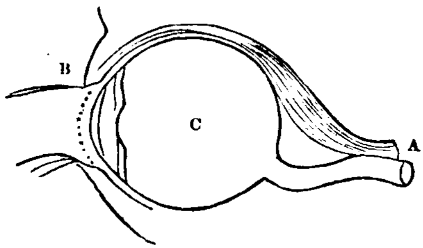
XX.

MUSCLES OF THE EYE-LIDS.

EVEN in the action of the muscles of the eye-lids, although the most exposed and familiar parts of any, there is something new still to be observed. The eye-ball is held betwixt the *levator palpebræ,* the muscle which raises the eye-lid, and the *orbicularis,* that which depresses it; the one as it elevates the eye-lid tending to protrude the eye-ball, the other to compress and restrain it.

In paralysis of the *orbicularis,* the muscle which closes the eye, the eye-ball is protruded; it starts more forward than is natural; the eye-lid is loose and flabby, and can be lifted like a bit of common skin.

It is from this protrusion of the eye-ball that the upper eye-lid is raised, and the lower eye-lid depressed, by one muscle. Anatomists have sought for a depressor of the inferior eye-lid, seeing that it is depressed; but such a muscle has no existence, and is quite unnecessary. The *levator palpebræ superioris* opens wide the eye-lids, depressing the lower eye-lid at the same time that it elevates the upper one. If we put the finger upon the lower eye-lid so as to feel the eye-ball when the eye is shut, and then open the eye, we shall perceive that, during this action, the eye-ball is pushed forwards. Now the lower eye-lid is so adapted as to slip off the convex surface of the ball in this action, and thus to be depressed, while the upper eye-lid is elevated.



The origin of the levator being at A, and the insertion into the cartilage of the upper eye-lid at B, the effect of the action of the muscle must be the protrusion of the eye-ball C to the dotted line. By the elevation of the upper eye-lid, the eye starts forward a little, and the lower eye-lid therefore slips off the lower segment of the eye-ball.

It is curious to observe how the eye-ball retreats in its condition of repose, and is protruded when about to be exercised in vision. High excitement, as in terror, when the eye-balls are largely unclosed, is attended with an increase of the sphere of vision produced by the protrusion of the eye-balls; a change remarkable both in the ferocious and timid animals, especially in the latter.

Such were the views of the motions of the eye-ball and eye-lids, introductory to a paper on the muscles of the eye—itself introductory to observations on the nerves of the orbit. The discussion relating to these is too strictly and minutely anatomical for our present purpose. It will be sufficient if I state the deduction,—that by the eight muscles around the eye, and the six nerves, whose extremities reach them, two sets of motions are provided; the first for the voluntary direction of the eye-ball in strict sympathy with vision; the other in connexion with the mechanical and hydraulic apparatus for the protection of the organ. When we enjoy the sense of vision, the voluntary muscles are excited; but, in sleep, another class preponderates, over which we have no voluntary power; and this is the condition of rest as well as of safety to the organ.

XXI.

REVIEW OF THE USES OF THE PARTS IN THE EAR.

We find late physiological writers acknowledging their ignorance of the functions of the particular structures in this organ; and we cannot therefore conceal that there is a difficulty in assigning the uses of the parts. Nevertheless, we shall now endeavour to explain our conceptions of this matter; and, at all events, there is enough to prove the main argument of design and of the fine adaptation of this organ to the laws by which sound is propagated.

The outward ear of man and animals is so obviously provided for collecting sound that there can be no cavil here. It is extended and moveable in those animals which hear acutely, and in some, as the bat, it is double, consisting of one expanded membrane within the other. And this brings to mind an assertion, that the membrane of the tympanum is affected by the vibrations of the side of the auditory tube more than by the direct impulse of the atmosphere against it; for if there be one conical expanded external ear within another, it is obvious that there must be a larger surface to receive vibrations and communicate them to the tube and membrane of the tympanum.

It suffices with some to say that the undulation of sound is received upon the membrane of the tympanum, and by it is communicated to the atmosphere within. But how is the infinite variety of sounds, all, in fact, that we hear, communicated simultaneously through the same membrane? In the first place, the membrane is not simple, nor is it muscular, but contains within it cords or fibres which run from its outer margin, converging towards the malleus. It is now that we look with great interest upon the experiments of Chladni and others on metallic plates. He strews dust upon one of these plates, and then brings out a note by drawing the bow of the violin upon the edge; when the sand, or powder, or dust, will arrange itself in regular figures. These figures are remarkable for their symmetry, dividing the circumference of the plate into equal parts, from six to forty; or the sand divides itself into circles having the same centre with the plate, and the diametrical and circular lines combine to produce an astonishing variety in the configuration of the particles. Here, then, we have a proof that, instead of there being a general undulation or vibration of the whole membrane of the tympanum, it may be subdivided, a motion taking place in its minute parts, and these having many nodes or centres which remain motionless; in short, we perceive a capability of motion in the membrane corresponding with the variety of sounds which we know to be propagated through it. And if we should imagine that the general surface of the membrane was unsuitable for so great a variety of compound motions, the chords visible upon its interior surface may be considered sufficient to allow it to correspond with every possible variety of note. (See fig., vol. i., p. 59.)

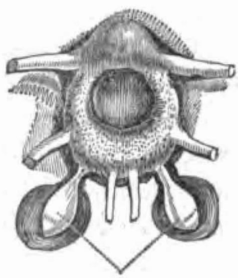
How satisfactory soever the ingenious experiments in acoustics and with musical instruments may be, there is a difficulty which has not been met in assigning the offices to some of the parts in the ear. The chain of bones in the tympanum undoubtedly communicates the sounds from the membrane of the tympanum to the proper seat of the sense, the labyrinth; and nothing is more easy than to conceive that the membrane of the tympanum, receiving an impulse, like a sail flapping by the wind, should communicate the same to the malleus and in succession to the other bones. But the difficulty arises from considering that it is not a mechanical impulse which is communicated, but a motion of sound. When philosophers teach us the nature of sound by throwing a pebble into a still pond of water and making us observe the concentric undulations: or by striking a cord and observing the motions which accompany the sound, and showing the harmonic subdivisions, we seem to have overcome all the difficulties of the science. But we encounter new difficulties when we are forced to conclude that all the combinations of sound in an orchestra, for example, are transmitted through a chain of bones, some of which are not greater in diameter than a horse hair. We are reminded that the undulations visible to the eye or felt by the finger are not the motions of sound, although they accompany them, and that they must be of a nature much more minute and delicate. There is no instance of one organ of sense conveying the knowledge of a quality of matter for the perception of which another organ is provided. Still, perhaps, these microscopic observations may assist our invention. When a powerful lens is applied to a metallic cord sounding, and we distinguish the brilliant particles on its surface, those particles have not the motions merely to and fro which are caused by the division and subdivision of the elastic cord: those brilliant particles dance in figures infinitely varied, combined of circles and angles which it is perhaps impossible to describe and reduce to any system. Such facts aid us in comprehending how different motions of sound may be communicated at the same moment.

It is ascertained that if a metallic rod be placed in contact with a sounding-board to which the sounds of many instruments playing in concert are communicated, and if that rod be extended to a great length, or if it be carried through a partition, so that we are out of ear-shot of the instruments, and if the rod communicate at its further end with another sounding-board, the motions of that board will be given out to the atmosphere and we shall hear the concert, that is, the combined sounds of the instruments, although necessarily faint. Here, then, the music must have been conveyed along the rod; and we have another proof that sound cannot consist of those coarser movements ascertained by the other senses, but of something so infinitely more minute that the particles in the rod may convey distinct vibrations simultaneously. These considerations certainly countenance our belief, that however fine the chain of bones may be which, passing through the tympanum, communicates between the external and internal ear, it is yet capable of a variety of motions corresponding with the sounds, of which the ear is susceptible.

What, then, is the meaning of this very obvious mechanical structure in the chain of bones in these little levers and their attached muscles? (See fig. p. 55, vol. i.) Are not the three muscles attached to the bone that is fixed to the membrane calculated to affect the tension of the membrane? If we take the illustration in the text, we must remember that the military drum is not so simple as it has been represented. The chords or braces, which pass outside the drum obliquely, are tightened by pushing down the knots of buff leather, and this not only stretches the parchment head of the drum, but tightens the snares or cords which run over the parchment of the reverse of the drum. In the military drum, it is the blow on the parchment that gives the loud and sudden sound; while the chords alter and prolong the sound. The three muscles which are attached to the malleus and through it to the membrane of the tympanum we must suppose may either brace or throw loose the membrane and its cords; as the drum is braced or muffled: and in this way the small muscles of the tympanum may have a resemblance in function to the fibres of the iris; they may guard the nerve of hearing as the latter does the nerve of vision. We had occasion to observe, that when a person is deaf from the disorder of this apparatus, and when he substitutes the ear-trumpet, he may hear; for the ear-trumpet, by its expanded mouth, collects the undulations of sound and concentrates them; but there is this imperfection, that the ear wants its power of adjustment; and the person is accordingly often timid in the use of his instrument with those who are not accustomed to speak to him, the sound of some voices being painfully harsh. Further, we may not hear a sound when called upon to listen to it, and yet when the particular sound is described, we do hear it; now it remains to be determined whether this be a power of adjustment in the ear, or owing to the effect of association in the mind.

It is supposed by some that there are two tracts by which sound is communicated to the labyrinth; that it passes both through the chain of bones and through the air in the tympanum. With regard to the last mode, I can conceive no cavity less suited to convey sounds. Instead of having a definite form like the tube of the ear, by which the vibrations might be received and directed inwards, the tympanum opens into the cells of the temporal bone, and presents the most irregular surface possible, and such as would inevitably break and destroy any regular sound. The extension of cavity of the tympanum is calculated to increase the elasticity of the air in the tympanum, but most certainly not to collect or to strengthen the sound.

With regard to the labyrinth, comparative anatomy lends us considerable assistance. Were vibrations of sound being communicated to the brain the cause of hearing, the brain itself would be the organ and no special nerve necessary. The brain in some animals, being placed in a cavity, and surrounded with fluid, is subjected necessarily to vibration. But we perceive that in addition an appropriate nerve and distinct organ are bestowed. There is here, in the cuttle-fish, very little apparatus in this organ, and it



This figure represents the form of the brain in the cuttle-fish, as an example of its very simple structure: A the simple auditory apparatus.

proves that the essential part of the ear is the nerve susceptible of sound, and not the exterior apparatus. Some sixty years ago, learned men in Italy wished to ascertain whether the lobster had the organ of hearing or not. The celebrated Professor Scarpa, then a young man, undertook to decide that matter; not by looking for the exterior organ, but by examining the brain and the nerves which go out from it. Finding that there was a nerve which stood in the relation of an acoustic nerve, he traced it onward and found it terminating in a little sac containing fluid, and open to the influence of the atmosphere by a small membrane which crossed the mouth of it. This was the just and philosophical mode of proceeding. There being, in fact, nothing in the brain itself, with respect to its exposure to tremours or motion, different from the auditory nerve, if that nerve had had merely to convey a vibration to the brain, it would have been superfluous, as the brain itself would have vibrated. Hence we perceive that an endowment of a nerve which shall be susceptible of the sense of sound is necessary, and consequently it is the primary and essential part of the organization. How the motions of sound shall reach it is another question.

Let us now carry along with us the fact that solids and fluids are much better vehicles of sound than the atmosphere; that it is the rarity and elasticity of the atmosphere which makes all that exterior apparatus which we have been considering necessary. Accordingly, an exterior ear is not wanted in the fish. If a man dive under water and carry a stone in each hand and strike the stones together, he is sensible of a stunning sound, and indeed of an impression on the whole surface of his body. In short, although it was once doubted whether water were capable of propagating sound, a hundred instances can now be brought forward to prove that it can receive or propagate every degree of sound and tone. Again, when we find that the solid parts of the head convey sounds, we perceive that in the fish there is no occasion even for an external opening, far less an external ear. An apparatus of a totally different kind is bestowed. Within a little sac of fluid a bone or concretion is suspended, which, being more solid than the surrounding fluid, receives the vibration and moves, necessarily producing waves or motion in the surrounding fluid, and consequently an agitation of the extremities of the nerve exposed to the fluid. A very simple but curious experiment of Professor Camper illustrates the effect of this structure: A bladder containing a marble and full of water being held in the hand, the slightest motion of the hand was attended with a vibration communicated from the water to the hand: the effect of the motion of the marble upon the surrounding water.

With respect to the semicircular canals above described, I am at a loss to understand what is meant by some authors saying that their use is not known. These canals consist of an elastic membrane full of fluid, with a nerve suspended upon the septum of one extremity: are they not then admirably suited to receive the impulses which are conveyed through the bones of the head? That they are so, is clear from their being found in the heads of fishes, where there is no access of vibration to the nerve except through the bone. But we are affected by the same when our head is on the pillow and we are awakened by people moving in the house: the alarm is through the solid bones of the head. And when the Indian puts his ear to the ground to hear a distant tread, he is substituting the communication through the solids and the bones of the head for the atmospheric impulses.

Again, let us recur to the proposition that sound is propagated to the internal ear in two ways: through the chain of bones and fenestra ovalis into the vestibule, and also through the air of the tympanum, and by the fenestra rotunda into the cochlea. There appear strong objections to this doctrine. It declares the chain of bones and their appended muscles and beautiful articulations to be altogether useless; for if the sound can be communicated through the air of the tympanum, what is the meaning of this complex apparatus? And if the bones of the ear communicate better, what is the use of the vibration coming by any other course? Let us understand, then, that the whole exterior apparatus—that is to say, the parts exterior to the labyrinth—are necessary only to perfect hearing, and that when they are all gone by disease, those essential parts of the organ which we see suffice in the lower animals, continue to receive sounds.

The apparatus of bones and muscles connected with the membrane of the tympanum (see pages 55, 56) is of more consequence than physiologists allow. It is essential to perfect hearing, even when the sound is conveyed through the solid bones. If we hold a watch between the teeth, the sound is propagated through the solid parts; but let us compress and close the outer tube of one of the ears, and the sound will be increased on that side. If a person, being deaf in one ear, put his watch close to that ear, he will not hear the ticking; but, if at the same time he presses on the tube of the other ear and closes it, he will then hear the ticking on that side. It appears that in this experiment, the sound propagated through the bones is not given directly to the nerve, but to the membrane and bones of the tympanum, and through them back upon the nerve. The air in the outer tube of the ear, being pent up by the pressure of the fingers and compressed, receives the vibration, reverberates on the membrane of the tympanum, and puts the apparatus within the tympanum into play.

Drawing a fair inference from the demonstration, it would appear that the impulses upon the membrane of the tympanum are communicated to the membrane of the fenestra ovalis, and that the opening called the fenestra rotunda, closed by a similar membrane, is for the purpose not of receiving impulse from without but of yielding to that impulse from within. For example, if we suppose a bottle of water full to the lip, and a bladder drawn over it so that not a bubble of air is contained, although that water must be admitted to be compressible, an impulse upon the bladder would produce no such effect as would follow were there a hole covered with a bladder upon the side or bottom of the bottle; for then each impulse upon the top would be attended with a yielding of the bladder below, and a consequent agitation in all the intermediate fluid. Thus, it appears to us that the use of the fenestra rotunda and its membrane is to give play to the membrane of the fenestra ovalis, and that without this provision, although there might be a general impulse communicated to the fluid in the labyrinth, like that communicated through the bones generally, there could be no wave or undulation. If the shutting of the Eustachian tube, D, page 52, vol. i., so confines the *air* in the large cavity of the tympanum as to render us deaf, what would be the consequence of the labyrinth (which contains *water*) being shut in on every side? The play, then, of the bones of the tympanum, and of the membrane of the fenestra ovalis and of the fenestra rotunda, is not only required to produce an undulation in the fluid within the labyrinth, but that undulation must take the particular course through the scala of the cochlea, descending into it by the scala vestibuli and ascending by the scala tympani. (See F, vol. i., page 52.) In this view it becomes interesting to consider the distribution of the nerve in the cochlea, since this internal part of the organ is so obviously connected with the finer exterior apparatus. We have learned that the nerve passes into the modiolus and extends to the edge of the lamina spiralis, so that the sonorous undulations continued through these passages must affect the nerve on two surfaces; and whether we consider the cochlea to be like the bending of the spiral turns of a wind instrument, or the fibres of the lamina spiralis to be like a succession of chords diminishing regularly in length, we can at least imagine that at one time the whole portion of the nerve may be brushed and agitated, and that at another it may be partially affected.

In short, the concavities of the central cavity of the labyrinth, the vestibule, may produce an eddying of the fluid, so that the motion shall be concentrated to a point, on which point there is seated a portion of the nerve; or the undulation may pass round the semicircular canals and affect the septum of each ampulla; or by being propagated through the cochlea it may touch fibres of the lamina spiralis of different lengths. All we mean to affirm is, that there is so great an extent and variety in the distribution of the acoustic nerve, and also in the canals and cavities, as fairly to give us reason for believing them to be the sources of that extensive scale, and of all the changes and combinations of sound which we enjoy through this sense.

XXII.

OF THE CIRCULATION.

Life in the animal body is attended with a never-ceasing change in the whole framework. Not merely is there a current of blood running in a circle, but all the things that enter into the composition of the animal body, solids as well as fluids, are under an influence that keeps them in incessant change. This, indeed, is the object or end of the circulation: for the blood contains in a fluid state what had composed the solid framework. We might say that the solid matter was resolved or melted, but that it is a vital action which thus reduces the texture to the condition of a fluid. At the same time that the blood contains what has been the material of the body, it consists also of new matter, the product of digestion and assimilation, and which is destined to take the place of the material that has been removed. The circulating blood is thus made the agent by which the revolution of the solid animal frame as well as of the fluids is accomplished.

We learn by this, that there is nothing permanent in the living body. We see, and perhaps without much surprise, that a part cut heals, that a part excavated or taken away is soon replaced, and in some of the lower animals that members cut off are actually reproduced: all this we see, but it requires fine experiment and accurate reasoning to enforce the conclusion that the animal body is always growing, always forming; and that this incessant revolution in the material of the frame is the grand distinction between the living structures of the animal body and machinery. In the former there is a principle of renovation incessantly at work, so that the action or exercise is attended with no wear and tear, but, on the contrary, the greater the activity the more perfect the structure, and what we term the healing process, or the reproduction of parts, is the continuance of an action which has had no interval.

It being absolutely proved that there is nothing permanent in the body, we leave the reader to consider the question, which forces itself upon him, "What, then, is it that gives identity? How comes the peculiarity of form and constitution and complexion to remain—or how does the memory serve us—when the material has been many times removed?" But we have rather to consider the grand operation by which these changes are wrought—the circulation.

Modern chemists have estimated that 5208 grains of charcoal are thrown off from the blood in twenty-four hours, and this uniting with 13,392 grains of oxygen in the atmosphere that is breathed, constitutes, with a due proportion of caloric, the carbonic acid gas which is discharged from the lungs. Other secretions are also disposing of the material of the body; and although these be necessary to health, it is the function of respiration which is the most directly necessary to life, and which is guarded by pain and anxiety experienced the moment that interruption is begun.

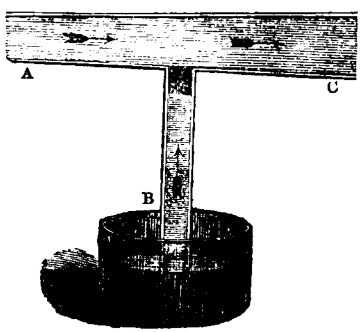
We may already comprehend how the blood flows in a great circle, taking up the material of the body by the absorbents and veins of the body, and throwing it off by the lungs: and how blood returning from the lungs, purified by exposure to the atmosphere, comes back to the heart to complete its circle. We readily conceive also how this pure blood is necessary to all the vital operations, to the nourishment and growth of the body; but it is not so easy to comprehend the manner in which the force of the circulation ever keeps pace with the condition of the body: active during the exercise of the body, reduced and equable during repose; or how the body generally will have the circulation moderate in degree, whilst an individual part being excited and in action shall be accommodated with an activity of circulation exactly apportioned to the necessity for it. It is not possible, on mere hydraulic principles, to explain how the blood shall descend to the toes or ascend to the head by one impulse, and yet with a force exactly proportioned to the distance and elevation of the member. Nothing is more admirable than the manner in which the heart, as the great engine in the centre, has its irritability and power of action united in close relation to the condition of the body. If the pulse is to be felt by the physician, the person must recline, for if he stand up, on hydraulic principles a greater force is required to move the upright column of blood, and the heart beats more rapidly; and this, especially, is more remarkable, if the person be sickly and weak. For the same reason no physician feels the pulse when his patient is anxious or perturbed, or at least he must calculate on the pulse being accelerated. These and many other examples might be brought to show that the circulation alters in correspondence with the position of the body, and with its exercise; and that it alters with the emotions of the mind, as well as with the changes in the position and movement of the frame. We learn from this that the heart, through its sensibilities, is the regulator of the circulating system, and that it is for this purpose that it has such extensive sympathies. These remarks we premise as reminding the reader that there are more things to be admired in the contemplation of the living animal frame, than can be brought under the head of the mechanism of the circulating organs, or the adaptation of the tubes to the known principles of hydraulics. It is, however, to these that we must now beg his attention.

XXIII.

OF THE VEINS.

Our author has taken up the notion, which indeed is conveyed in anatomical books, that the veins are irregular in their form and course. We hold this to be a dangerous admission; first, because it leads to the supposition that there is a certain imperfection, and as it were negligence, in the structure of the frame; and secondly, because it induces the inquirer to be satisfied with a very superficial survey. The veins are considered as mere conduit-pipes, to carry back the blood from all parts of the body to the heart. But they are much more; they are reservoirs. Where could that large proportion of blood which is necessary, be deposited with more safety to life than in those recesses or interstices left by the bones and muscles of the body? But whilst this object is secured, another more important one is attained by the turning and twisting of the veins into the crevices and unoccupied spaces: for they become thus liable to be pressed by the action of the muscles; and so it comes about that the blood is permitted to move on slowly in these recesses whilst we lie inactive, but when we are aroused into action, it is pressed onward, the dimensions of the reservoirs are diminished, and the blood is accumulated upon the more active heart, and is ready to answer the demands of the system which that very activity requires. The sensations at the heart exciting the respiration, the chest is expanded, and the veins enlarged; and by the alternate suction and compression upon those great veins, the heart is liberally supplied. By this arrangement, then, there is ever a correspondence preserved between the activity of the body and the rapidity of the circulation. For this is the sequence of actions—1. We rise into activity; the blood, which was slowly circulating, is pressed forward to the heart: 2. The heart is distended and excited: 3. The sympathy or bond of union between the heart and lungs makes a call upon the respiratory action; and the decarbonization of the blood takes place more rapidly: 4. The return of arterial blood from the lungs to the heart is accelerated, and the heart regulates the action of the arteries: 5. The increased arterial action supports the exercise of the muscular frame; and, thus, there is a circle of relations established arising out of that very seeming irregularity of the veins; their position and general condition ensure an acceleration of circulation corresponding with the activity of the muscular system.

True it is that, in comparing the branching of the veins with the arteries, there seems to be, as anatomists have taken pains to show, an appearance of clumsiness and irregularity in the former compared with the latter; but they have not inquired whether there was a reason for this variety —whether the distinction in the manner of a small tube joining a larger, accords with the direction of the fluid in these tubes or not—and yet this is a question very naturally suggested, if we have a firm conviction that in the natural body nothing is formed imperfectly, or by chance. Accordingly, it does appear that, in the distribution of water-pipes, it is very necessary to attend to the angle at which a small pipe joins a larger. If a pipe be fixed into another contrary to the direction of the stream, the discharge into that lateral branch from the larger tube will not only be much smaller than what we might estimate by the diameter of the tubes it should be, but in certain



circumstances it will discharge nothing at all;

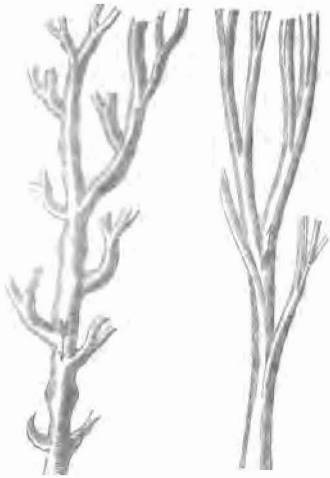
nay, the water will be drawn from the lesser tube into the greater.

Bernouilli found that when a small tube, B, was inserted into the side of a horizontal conical tube, A, in which the water was flowing towards the wider end C, not only did no water escape through the smaller tube, but water in a vessel, at a considerable distance below, was drawn up through the lesser tube into the greater.

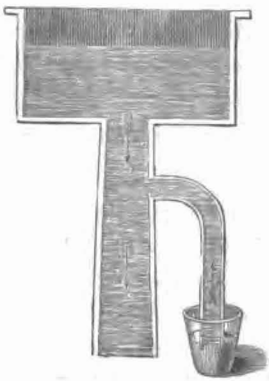
With these facts before us, we turn with interest to the curves of the arteries and veins, seeing that the contained fluids flow in the one from the trunk to the branch, in the other in an opposite direction from the smaller to the greater vessel.

And now, if, instead of taking the artery as the important vessel, and the vein as less so—and therefore negligently contrived, we consider both of them to be important and perfect—we ought to expect that their course and curves should differ.

In the artery, where the blood is passing from the heart towards the extremities—that is, from trunk to branch—the branches slightly diverge from the direction of the stream in the trunk; whilst the branch of the vein, where the blood is passing from the lesser into the larger vessel, enters abruptly and at right angles. From this it appears, that if we could imagine such a malformation as that the offices of these vessels were changed, congestion would immediately take place, and the circulation could not be carried on.



It appears, further, that if the veins were rigid, or placed in circumstances where their sides remained apart when wounded, instead of blood escaping, air might be drawn into them through the expansion of the chest in breathing—and this is a most important circumstance; for when such an accident takes place, death follows instantaneously. When a reservoir is emptied by a perpendicular tube, into which a smaller tube is inserted, the water descending by the larger tube instead of escaping by the lesser, will draw the water up through that lesser tube so as to empty the glass in which its lower end is immersed. By this we see that there may be points on the sides of tubes conveying fluid, in which the pressure may be negative; and we are made aware that the arrangement in question, instead of being a negligent or irregular joining of the branch to the trunk, is, on the contrary, a



provision for the lesser tube entering at a proper angle into the side of the greater one.

If two tubes join to form a larger tube, and a hole be bored at the angle of their union, and if the water flow from the lesser tubes into the greater tube, no water will escape by the hole: in other words, there is a point of negative pressure. Now it is remarkable that the vessels which are called absorbents enter into the venous system at the angle of union of the great veins; that is, at the point of negative pressure.

XXIV.

ON THE ARTERIES.

There is perhaps no finer proof of the adaptation of the apparatus of circulation to the principles of hydraulics than the fact of the increasing diameters of the arteries as they recede from the heart. Mr. John Hunter took great pains to prove this: and he did demonstrate that when a great artery divided into two branches, the united areas of the branches were greater than the area of the trunk; that when the branches subdivided, the united areas of the subdivisions were greater than the areas of the vessels from which they were derived, and so on to the extreme vessels. Reflecting on this, it is interesting to find that the engineer in laying down pipes comes practically to the conclusion, that a pipe dividing into two branches, whose united areas are exactly equal to the area of that from which they proceed, will not deliver the same quantity of water that would have flowed through the greater tube. He discovers that he must take into account the attraction and friction of the fluid upon the solid, and that the smaller the calibre of the tube, the surface of attraction or friction will be proportionably the greater. Does not this fact coming out in practice prove to us why the united areas of the smaller branches of the artery are larger than that of the trunk from which they are derived? If any further explanation be necessary it is this —that the water flowing in a tube runs more rapidly in the centre than at the sides—or, in other words, that there is a certain attraction or friction at the sides. We see this in standing by a flowing river; the friction of the water against the bottom and the sides retards the stream, whilst the velocity of the current is greatest in the middle. As the water in the river is delayed at the bottom and sides, so is the fluid nearest the sides of the tube retarded by the friction between the fluid and the solid. Thus we see a remarkable coincidence between the increasing diameters of the circulating vessels, and of tubes laid down upon accurate hydraulic principles.

From the diameter of the arteries being larger as they recede from the heart, two advantages are obtained; first, that the blood is driven on with greater ease; and secondly, that the extreme arteries become in some measure like the veins, reservoirs of blood. A man of middling stature has thirty-three pounds of blood in his circulating vessels; and did the vessels not enlarge as they receded from the heart, there would be no place for the deposit of this great quantity of blood.

We may venture upon some further illustrations.—A stream of water, unconfined, will take a very different form if falling by its own gravity from what it will do if forced in any other direction, by a *vis à tergo*. When water is poured out of a vessel, it acquires velocity as it descends; the column is largest above and drawn fine below, because it is increasing in velocity, and the stream that has a greater velocity must be smaller in diameter: but continuing to descend, the stream acquires such a degree of velocity that the atmosphere offers resistance, and then it again spreads out. But a column of water sent upwards as a *jet d'eau*, instead of contracting as it ascends, enlarges. The fluid is retarded as it mounts; and the stream being still propelled from below, it is forced between the filaments of the column above and disperses them, enlarging the column as it ascends and giving it a conical form. Hence it follows that if water is to be discharged from a reservoir along an horizontal tube, it will flow more rapidly if the tube be a cone, with its lesser end inserted into the reservoir; for the weight of the water in the reservoir still being a *vis à tergo*, and the stream from behind forcing itself between the filaments of the column and so dispersing them, it is clear that the increasing diameter of the tube will correspond with the natural enlargement of the column of water, and give it an unimpeded exit. Here, then, we have another explanation of the increasing diameter of the arteries to receive the blood propelled by the heart.

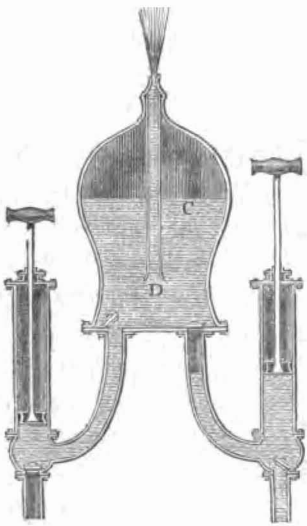
In laying pipes for a *jet d'eau*, the ascent of the water will be diminished by any sudden angle in the tube; and the *ajutage* must rise from the horizontal pipe with a gentle sweep, or the jet will not reach so high as it ought to do, from calculating the height of the water in the reservoir. This circumstance explains the parabolic curve which the great artery takes in going off from the heart; it explains also why the branches of this great artery go off at different angles, and why near the heart the branch goes off at a greater angle from the direction of the stream *.

We have, perhaps, said enough to remove the notion, that there is anything like irregularity in the course and distribution of the vessels of the living body. But there are some other laws of hydraulics which give interest to the structure and action of the circulating vessels. The elasticity of the coats of the artery is a subject of importance in surgical pathology, and has very

* This refers more especially to the intercostal arteries.

properly been deeply considered. This power has not, however, met with sufficient attention as one of the forces propelling the blood.

The law of inertia is easily comprehended as it regards solids. Every thing about us proves that it is more difficult to move a body at rest, than to accelerate it when it has been put in motion. The same law holds of a column of water in a pipe: it is easier to keep it in motion than to put it in motion from a state of rest. From this it follows that, in propelling water through a pipe by a forcing pump, as the impulse is given at intervals, and as the whole column is at rest after each stroke of the piston, much of the force must be lost. Now if the heart contracted and propelled the blood into the artery, and there was then an interval of rest, during which the blood was stationary, the next pulsation of the heart would be in part at least exhausted in bringing the blood from a state of rest into a state of motion. This will be best understood by following the successive contrivances which the engineer has employed, in raising water, to keep the column in motion uninterruptedly, and therefore to use his power in accelerating the stream, not in bringing it from a state of rest into a state of motion. The first idea was to have two forcing pipes instead of one, so that one stroke should succeed another without interval. But it was soon discovered that there was a difficulty in adjusting exactly the two forces; and so it was found that three forcing-pumps were better than two, as more effectually providing against any interruption to the motion of the stream; the second filling up the interval between the impulse of the first and third. This multiplication of the parts of the engine shews the desire of the engineer to avoid interruption in the stream. But it does not so well illustrate our proper subject as the next



invention, which was to employ an elastic power;

and the engineer contrived it thus. A portion of air is confined in a reservoir; the pipes of two forcing-pumps are carried into the reservoir, and they fill it half full of water, C; the mouth of the pipe, D, which is to convey away the water, reaches into the water in the reservoir. As the water rises, the air is compressed: so that, although the pumps act alternately, the elasticity of the contained air acts uninterruptedly in pressing on the surface of the water, and raising it by the tube, D, in an equable stream. The elasticity of the contained air fills up the interval between the actions of the pumps, and admits of no interruption to the force with which the water is propelled upwards.

Surely these are sufficient indications of the necessity of three powers acting in propelling the blood from the heart. The first is a sudden and powerful action of the ventricle: the second is a contraction of the artery, somewhat similar, excited by its distention: the third, though a property independent of life, is a power permitting no interval or alternation; it is the elasticity of the coats of the artery: and these three powers, duly adjusted, keep up a continued stream in the blood-vessels. It is true that when an artery is wounded, the blood flows in pulses; but that proceeds from the regular acceleration of a jet which yet has no actual interruption. Were not this continued flow of the blood provided, there would be a loss of power, at each pulsation of the heart, in carrying the blood from a state of rest to a state of motion; and if we consider how many pulses there are in the twenty-four hours, 80,000, we may make some estimate of the loss of vital power that would accrue had there been a neglect of the law of inertia in the apparatus of circulation.

XXV.

MICROSCOPIC PHENOMENA IN THE ANIMAL BODY—MOLECULAR MOTIONS—CILIARY MOTIONS.

We have noted the judicious course pursued by Dr. Paley, in preferring the proofs of design drawn from the structures of our bodies, which secure our existence, or minister to our comforts or enjoyments; for in these there may well be perceived the object of the provisions, and the mode by which they are attained; and this supports us in a due estimate of ourselves,—seeing that there is so much care of us, and that our bodily and intellectual endowments have so many relations to the system of nature. By the aid of the telescope or microscope we are equally carried, as it were, out of ourselves, to view nature foreign to us. If, it has been justly observed, in contemplating the heavens with minds ill confirmed as to the intentions of Providence towards us, the study is far from being consolatory, the same may be said of the microscopic world. The discovery of the universal prevalence of life, of animals within animals, of the inhabitants of a drop of fluid as difficult to enumerate or arrange as those of the ocean, gives rise to thoughts which do not flatter our self-importance, more than the contemplation of the magnitude of the heavenly bodies, and the extent of space through which they range. It will, therefore, be tending to the object of this volume to show that with the microscope, that is, by observing the atoms of our frame which are invisible to the naked eye, we discover motions and actions, both of inorganic and animated particles, which tend to the preservation of life, and to the performance of the offices in the animal economy, fully as remarkable as the contractions of the heart, or the play of the lungs.

It will be necessary to the correct estimate of the facts which we have to mention, that we advert to a curious discovery of Mr. Brown, relative to the motions of inorganic molecules. This gentleman's celebrity is of a kind which may not readily be comprehended by some readers; for his retired and philosophical habits cause him to occupy a small space in society at home, in comparison with that reputation which extends wherever science is cultivated. He was directed to this subject by a motion visible in the pollen of plants, when under his microscope, which led him to further investigations; and he found that when inorganic as well as organic bodies were minutely divided, and floated in a drop of water, active motions were seen in the molecules. The motions of these particles are different from those of animated matter. The molecules are spherical, and between 1-20,000th and 1-30,000th of an inch in diameter. I have myself seen these, and nothing can be more surprising than their evolutions, like figures in a dance, apparently produced by the attraction and repulsion of the particles themselves. It might be supposed that the rapid evaporation from the surface of the drop would produce eddies within it, and that these molecules were carried by the circulation of the fluid; but the ingenious mode by which Mr. Brown prevented the evaporation of the watery particle, by surrounding it with oil, whilst the motions of the molecules continued, refutes this hypothesis, and inclines us the more to rejoice that the curious phenomenon was discovered, not accidentally, but by a philosopher.

Indeed, whilst looking upon these molecules, we are surprised by bodies, obviously animalcules, jostling them, and darting across the field of the microscope; and the natural reflection is, how much more minute must the constituent parts, or molecules, of these animalcules be! Their motions are not fortuitous, or owing to any polarization or influence external to them, as galvanism or magnetism: they have instincts and appetites, and are susceptible of excitement: their bodies are nourished by digestion, or imbibition: they have circulation, though it may be with a different apparatus from that of larger animals: their circulating fluids, their containing vessels, their apparatus for motion, imply that the ultimate molecules of their composition must be infinitely small, even in comparison with the minute particles which we are contemplating: and this we state, to do away with those speculations which men are prone to indulge in, when they suppose that they have at last attained a sight, in these active molecules, of the ultimate particles which constitute the frame-work of animals *.

Another class of facts drawn from the minute world is no less wonderful than the motion of these "active molecules:" we allude to certain vibratory motions, or, as they are termed, *ciliary* motions, on the mucous surfaces of animals. They are somewhat analogous to the actions of the rotatory apparatus of some of the infusoria. Both the respiration and the prehension of food in these animals are accomplished by an influence of their bodies, whereby a current is kept up in the surrounding fluid; a fresh stream by this

* Animalcules are visible in the microscope, so minute, that it is estimated that a million of them do not exceed in magnitude a grain of sand.

means plays over the apparatus of their respiratory organs, whilst in some the minute particles of nutritious matter in the fluid are brought in contact with their prehensile organs.

The soft aquatic animals, called porifera, have many orifices on their surface, into which the surrounding fluid is drawn, and being then brought into a common sac, it is expelled through a larger central mouth *. We can conceive an action of these pores, by which the water may be sucked in and propelled; but the more curious action is that of the cilia, or filaments, with which their tentacula are covered. These cilia have a motion which produces a vortex in the fluid, and tends to convey the floating nourishment towards the mouth †.

This well-attested fact leads us to comprehend the phenomenon which is the principal object of this note, and explains what is meant by "ciliary motions." It is here necessary to mention that what anatomists term the mucous membrane is the lining of all those tubes and cavities of the animal body which open outwardly, in contradistinction to the membranes which line the proper cavities of the body, and which are called serous membranes. It is of itself a circumstance tending to the support of the conclusions to which

* Dr. Grant. † Spallanzani.

the whole arguments of this book point, that the fluids thrown out to lubricate these surfaces are various and appropriate to the nature of the cavity. The membrane which is continuous all around, and has no outlet, must be moistened by a fluid which is to be absorbed again; but the surface of the cavity which has an outlet is moistened by a fluid which is to be discharged as from an emunctuory.

This brings us to the fact above referred to, which, if the observation has been correctly made, is by much the most extraordinary in the whole animal economy*. A portion of the mucous membrane of an animal recently killed is placed, with great nicety, under the field of the microscope, and in water: some fine particles, which will float in the water, are then added. What has been used with most advantage is the black pigment of the eye, which is easily diffused, and the particles of which are very minute. The experimenter is here cautioned to distinguish the molecular motions discovered by Mr. Brown, from those now to be described. A rapid vibratory motion is to be seen on the surface of the membrane, and these motions produce a current in the fluid in contact, which is made apparent by the floating of the minute particles of the pig-

* First observed by Purkinje and Valentin.

ment. The remarkable part of this phenomenon is the direction of these currents. The cilia, or small filaments projecting from the membrane, move in such a manner that the current is always directed towards the outlet of the cavity or tube; and thus it is conjectured that a new source and kind of action, independent of muscularity, (that is, the irritability of the grosser muscular fibre,) is provided for the gradual and regular ejection of the secretions from these tubes and cavities which enter deep into the animal structure. In this country these extraordinary endowments of the living surface are under the examination of one* who will prosecute the subject with philosophical precision, and the result of whose inquiries may be expected with an interest proportioned to the important nature of the facts.

* Dr. Sharpey, of Edinburgh.

XXVI.

ON LIFE.

When we survey the discoveries in the physical and abstract sciences, our wonder and admiration are excited by the grasp and various powers of the human mind; but we learn, also, that men acquire a habit of viewing objects, and of thinking, which trammels them, though possessed of the highest genius, when they change abruptly the subject of their studies.

The life of the body is a study new to science, and it has no natural alliance with any of the higher branches which occupy men of intellect; yet it requires a great reach of thought. Those who follow intricate mathematical deductions, calculate the return of comets, estimate the magnitude and attraction of the sun and planets, and even extend their investigations to the fixed stars, come to the subject as much under the influence of habit as the artisan who tries to accomplish by the dexterity of his hand, that for which a different manner of working has unfitted him. This may be a humiliating consideration, yet it must be acknowledged, or we shall never discover by what hypotheses we have hitherto been misled;

nor can we be directed in a course of observation likely to advance the science of Life.

The chemist is in the habit of observing the laws of invisible powers, of elective attraction, of heat, and of electrical, or galvanic, or magnetic influences. He makes a step, from the observation of the mere ponderable and visible qualities of matter, to the study of laws which govern that which can neither be weighed nor confined; and we should imagine, therefore, that the process of his reasoning would prepare him for comprehending more easily the influence of life, as exhibited in the phenomena of the animal body. But it has been far otherwise. The chemist, when he commences the study of physiology, instead of pausing and considering that he is about to enter on a new region, where phenomena unexampled before are to be presented to him, or are to be seen through different media, and the forces estimated by different means, carries along with him habits of thinking which promise no improvement in this new field; and, coming encumbered with all his apparatus, proceeds to measure that property which gives sensibility, motion, and thought, by the instruments he has hitherto employed in marking the current and force of electricity; and regards the brain as no more than an electric pile discharging at intervals along the nerves the fluid successively developed. Such are the false analogies which satisfy ingenious minds, so that they cease from inquiry, and leave science stationary. The mathematical and mechanical physicians long retarded the true knowledge of physiology; and we are now nearly as much embarrassed by the fashion of the day, of applying, to investigate the laws of life, the mode of reasoning which has been successful in the chemical sciences. There are but two men who have enlightened us on the doctrine of the life of the body, Haller and Hunter—and this is, in other words, saying, that it is altogether a recent science.

It is necessary to premise thus much, that the reader may not feel disappointment, if he fail, at first, in attempting to comprehend the subject. What does he understand by life?—That intelligence, feeling, and motion, which he sees manifested in the animal body. If, in this understanding of the term, he hears that Mr. Hunter discovered that there was life in the blood, it is possible that he may receive the announcement with the same ridicule with which the world at first heard it. But let us see how the subject opened upon Mr. Hunter's mind. He was engaged in minute inquiries into the gradual development of the chicken in the egg. On breaking one egg it was found perfectly sweet; the next was in a high state of putrescence. What, then, was the difference of their condition? Now let us not confound this question with what is termed organization. The chick at this time is concealed within a vesicle not larger than the head of a pin. It is the white and yolk of the egg that we are examining. Here is no heart, or vessels, or brain, or nerves, or anything of an animal body. The question of organization, then, is put quite aside. Nevertheless, Mr. Hunter conceived that the difference between the putrid and the sweet egg depended upon the influence of life, which in the latter counteracted the chemical affinities, and prevented the matter from falling into a putrescent state. If then, said he, the matter of the egg has that property of life to check and control the affinities which all matter divested of life is subject to, has it also the power of resisting the changes of temperature? And now, upon comparing the putrid and the living egg, he found that the latter resisted freezing; and he thus showed that the property which resists putrefaction is allied to the property of the animal body which preserves it in a uniform heat, though exposed to the changes of temperature in surrounding bodies. We see by this that a portion of matter in an egg, or in a seed, shall be endowed with a principle, which, however obscure, we perceive by its effects.

Thus, living matter is under the influence of laws totally distinct from those which govern dead matter. What shall we call this peculiar property? We have acquired a notion of life by witnessing the effects of many causes combined in the whole animal. Motion is in general the result of these; and so we associate life and motion. Mr. Hunter showed that each part of the body which possessed life exhibited it by different phenomena. He said truly, that when the muscle cut off from the animal recently killed still palpitated, it was by its property of life. Accordingly, when a portion of the blood was withdrawn, he observed that it exhibited properties totally different from dead matter: it was drawn a fluid; and this fluid presently coagulated. What, said his opponents, is there in this? Do we not see a fluid jellying, and becoming solid; and is this to be a proof of life? But Mr. Hunter demonstrated that the coagulation of the blood was not in any respect like the formation of a jelly; that heat neither accelerated nor prevented it; that it took place whether the fluid was left quiet or stirred; that nothing prevented the blood becoming solid but the contact and influence of the living vessels of the body. He showed, also, that the blood could be deprived of life or killed, and then it no longer coagulated. In short, he compared this property of coagulation in the blood to the contraction of the muscle; and, among other remarkable properties in the blood, he pointed out the coincidence, that when a man was killed by lightning, the muscle did not stiffen in death, that is, it did not contract, neither did the blood coagulate.

The next step of Mr. Hunter was to combat those who would represent the body as bearing a resemblance to machinery moved by a weight. In the machine, he said, the weight of the jack-stone is conveyed from one lever to another, and from one wheel to another; but what is there in this analogous to motions of the living body? Take away one of these wheels, or levers, there is no property or power in it; take a part of the body, and it has life, not as a property common to all the body, like that of gravitation in dead matter, but each portion has that endowment of life which is demonstrable or evident by distinct phenomena: and then he adds, true it is, that there is the example of beautiful machinery in the animal body, but how much more admirable are the different endowments of life which, corresponding together, minister to the intellectual being! One part has the property of receiving impression, another has the property of transmitting it, though it could not receive it. The mind thus approached and influenced, gives out its mandate by cords totally distinct, and with different properties: these have no motion in themselves, but they arrange and control the moving organs of the body, which give locomotion and agency. The whole body, then, is a collection of parts, possessing different endowments of life, exhibiting, by different phenomena, the presence of that life; and these different endowments have a bearing to each other, or a systematic arrangement, by which the communication is established between the mind and the external and material world.

Mr. Hunter illustrated the subject thus:—Death is apparent or real. A man dragged out of the water, and to appearance dead, is, notwithstanding, alive, according to the definition we have given. The living endowments of the individual parts are not exhausted. The sensibility may be yet roused; the nerves which convey the impression may yet so far retain their property, that other motor nerves may be influenced through them; the muscles may be once more concatenated, and drawn into a simultaneous action. That vibratory motion which we have just said may be witnessed in a muscle recently cut out of the body, may be so excited in a class of muscles, for example in the muscles of inspiration, that the apparently dead draws an inspiration. Here is the first of a series of vital motions which excites the others, and the heart beats, and the blood circulates, and the sensibilities are restored; and the mind, which was in the condition of one asleep, is roused into activity and volition, and all the common phenomena of life are resuscitated. Such is the series of phenomena which is presented in apparent death from suffocation; but, if the death has been from an injury of some vital part, the sensibilities and properties of action in the rest of the body, though resident for a time, have lost their relations, and there is a link wanting in that chain of vital actions which restores animation. Here, then, there can be no resuscitation; and the death of the individual parts of the body rapidly succeeds the apparent death of the body.

We perceive now that our original conception of life and the terms we use respecting it, in common parlance, are but ill adapted to this subject when philosophically considered. We early associate life and motion so intimately that the one stands for the other. If we then investigate by anatomy, we find a curious and minute mechanism in operation, an engine and tubes for circulation, and, in short, an internal motion of every particle of the frame; and the anatomist is also led into the error of associating in his mind life with motion and organization. But when we consider the subject more closely, and divest ourselves of habits and prejudices associated with words, we perceive that, without making any vain and even dangerous attempt at definition, life is first to be contemplated as the peculiarity distinguishing one of two classes into which all matter must be arranged; the one class, which embraces all living matter, is subject to a controlling influence which resists the chemical agents, and produces a series of revolutions, in an order and at periods prescribed; the other, dead matter, is subject to lapse and change under chemical agency and the common laws of matter.

Let us examine the body of a perfect or a complicated animal. We find each organ possessed of a different power. But there is as yet no conventional language adapted to our discourse on this subject, and that is the source of many mistakes; for when a man even like Mr. Hunter had his mind illuminated upon this science, how was he to frame his language, when every word that he used had already a meaning which had no reference to the discovery he had made—to the distinct qualities which he had ascertained to belong to the living parts?

The progress of science in the present day, although it does not bring us nearer to the comprehension of the nature of life, yet furnishes us with such analogies as enable us more easily to comprehend how this principle may be combined with the material of an animal body, and yet be perfectly distinct from it. The discoveries which have led to the atomic theory, and to that of the molecules of bodies being under a polaric influence, leave us with the impression that the minute particles of common matter (in contradistinction to living matter) are under an influence which may be bestowed or withdrawn: that as the index of the compass points to the north by no property of the metal itself, but through an influence given to it and existing around it, so do the most minute particles of bodies arrange themselves by some such superadded influence, and partake of polarization. If, then, according to the prevailing opinion of philosophers, everything we touch, or see, or taste, all matter, in short, exhibits qualities arising from the arrangement of particles infinitely minute, and that arrangement resulting from an influence exterior to them, or superadded to them, does it not facilitate our conception of a power or property bestowed on what is termed living matter and yet essentially distinct? The difference between dead living matter will then appear to be, that in the one instance the particles are permanently arranged and continue to exhibit their proper character, as we term it, until by ingenuity and practice some means are found to withdraw the arranging or uniting influence; and then the matter is chemically dissolved: resolves into its elements, and forms new combinations: whilst the life continues, not simply to arrange the particles, and to give them the order or organization of the animal body, but to whirl them in a series of revolutions, during all which the material is passive, the law being in the life. The order and succession of these changes and their duration do not result from the material of the frame, which is the same in all animals, but from that influence which we term life, and which is superadded to the material.

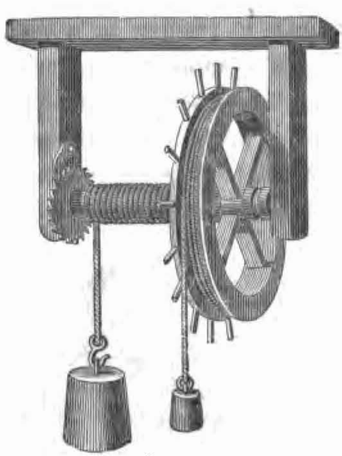
XXVII.

ILLUSTRATION OF THE WORKS OF A WATCH.

(See beginning of Chap. I.)

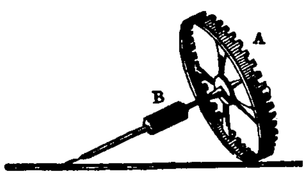
Many, perhaps most, persons carry watches, without ever thinking how such pieces of mechanism become a measure of time. This incurious habit is hurtful, for it may prevail to the neglect of other objects. We must suppose such persons to be quite indifferent to the structure of their own frame, by which they move and have so many enjoyments. The subject forms a good lesson in mechanics for a youth. Let him look into his watch, and learn how the wheels act, and how all are regulated by the balance, to measure time.

When men are advanced in science, they have sometimes little objection to see the particular subjects of their study involved in mystery. They are apt to deliver things in the form of a paradox. Thus they will affirm that the power of the hand, exerted through a machine, may raise a weight of many stones, and that one pound may weigh up one hundred. We are entitled to say, that the thing is impossible as the mechanist literally states it; that the props of the machine, the centre of the levers and the axles sustain by much the greater portion of the weight; and that the power of the hand is only given in addition to a weight which, though small, has, by the distribution of the force on the fixed points of the machinery, become balanced against the greater weight to be raised. This is obvious in the simplest form of a machine, *the wheel and axle,* when we see it at rest, and the lesser weight balancing the greater. In this figure the lesser weight and the greater weight are both sustained by the axle, and rest on the beams which sustain that axle.



Call the lesser body the *power,* and the greater body the *weight;* and the motions of these will be in proportion to their distance from the centre of the axle. Accordingly, we may measure the space through which they move, by pulling on the lesser weight, and seeing how much of the rope is uncoiled in one revolution of the wheel, and comparing that with the length of rope coiled up round the axle in the revolution, and consequently in the corresponding time.

A watch is an instrument where a set of wheels are made to revolve with a uniform velocity, and at a certain rate, so as to become the measure of time. When this motion is obtained, an index, or hand, is put on the axis of one of these wheels, and thus made to revolve on a dial, where the fractions of the revolution are marked. Two or more hands may be applied to different wheels, and these will indicate the subdivision of time in which the several wheels revolve in a minute, an hour, or in twelve hours.



In this figure, A is the wheel, and the notches, or rather the projecting points on it, the *teeth* *. B is the *pinion*, and the teeth on it are technically called the *leaves*. This is the wheel and pinion, and we perceive the resemblance to the wheel and axle. The teeth of the wheel move with a rapidity in proportion as the circumference of the wheel is distant from the axis or centre of motion.

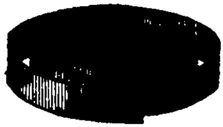
The wheel and pinion may be used either to accelerate motion, as when the power is applied to the pinion, or to diminish it, as when the power is applied to the teeth of the wheel, and conveyed through the leaves of the pinions to another wheel.

If there be forty teeth in a wheel, and this wheel plays into the pinion of another wheel having ten leaves, ten of the teeth of the first wheel will cause the second to complete its circle; and as there are forty teeth in the first wheel, the second will revolve four times for one of the first.

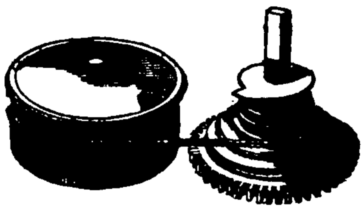
If things were reversed, and the motion commenced in the second wheel, so as to be communicated to the first, the mechanism would then

* The resemblance in these teeth to the jagged edge of a spur explains why certain wheels are called the "*spur-gear*." The engraver has here substituted, for my sketch, a crown wheel, that is, one where the teeth stand on the edge of a circlet, and parallel to the axis.

have the effect of diminishing the motion to one quarter. In both these ways are the wheel and pinion employed in the watch.



The power moving the wheels of a watch is the spring; it is here represented relaxed, as when the watch is run down.



On the left hand of this figure we have the *barrel*, a cylindrical box, in which the spring is coiled; and the extremity of the spring in the centre of the coil being fixed to an axle in the centre of the barrel, while the outer extremity is attached to the inner circumference of the barrel by a steel pin, the barrel must thus turn round as the spring uncoils.

The pyramidal body on the right is the *fusee*. In winding up the watch, the key is fixed on the pivot of this body, turns the fusee, and through the chain which joins it to the barrel, the barrel is also turned round, and the spring within wound close up to its axle. When the key is removed, the spring acts, the barrel slowly revolves, and the chain, wound upon the barrel and drawing on the fusee, turns the fusee round. On the base of this body we observe the spur teeth of a wheel. This wheel is the source of all the movements in the watch.

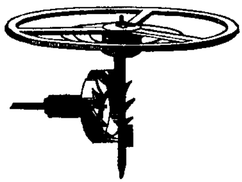
We must not neglect to observe a pretty contrivance to make the mechanical power of the fusee correspond with the diminished power of the spring as it uncoils. The spring exerts the greatest force when it begins to uncoil itself, and this force is diminished as it relaxes. To correct this inequality the fusee is formed. It is an axle so contrived that, with the varying power, the motion shall be uniform, and for this purpose it has the form of a truncated cone with a spiral groove which receives the chain. When the spring is acting with the greatest intensity, the chain pulls on a part of the fusee, not much removed from the centre of its revolution, and therefore with a small leverage; but when the spring acts feebly, as the spiral groove becomes farther and farther removed from the axis of the fusee, the chain is uncoiled from it with a greater lever power.

The great wheel on the base of the fusee checks into leaves of the pinion of the second or central wheel, and that moves, in succession, the third and fourth wheels. But before we estimate the effects of the respective wheels and pinions, we shall pass to the scapement, or balance.

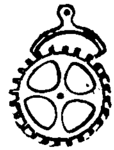
The effect of the scapement is to preserve the moving power, or "sustaining force," uniform, to equalize the effect of the spring on the work; for although this is in part effected through the fusee, it is not done sufficiently.

It is interesting and improving to observe, in the history of philosophy, how occurrences the most familiar become important when applied by genius to the arts. If a bell-rope hang free, and especially if a weight be appended to it, it will swing a long time. If we should chance to note the regularity and time of its motion, and so leave it, on returning, if it move at all, its motion from side to side (or its oscillation) will be performed in very nearly the same time as at first. Familiar and simple as this is, it is the *pendulum*, and the measure of time; and we can easily comprehend that if a rod, thus swung, be so appended to the work of a clock, as to receive a slight impulse, sufficient to keep it in motion, it will re-act on the clock; and if the motions of the wheels be nearly in accordance with the oscillation of the pendulum, it will preserve the motion of the whole machinery correct.

Accordingly it is easier to make a clock than a watch; for in a watch some substitute for the pendulum must be found; and the substitute is a very delicate piece of work, called the *scapement*.

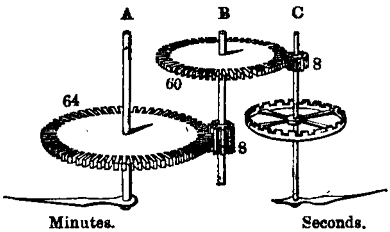


The upper wheel here is the balance-wheel, within which a fine hair spring is coiled. This spring is alternately pulled and let go by a motion communicated to the wheel, and the spring, by the regularity of its motions, answers the purpose of the pendulum. The notched wheel below is the scapement wheel; two projecting *pallets* on different faces of the axle of the balance-wheel fall in succession between the teeth of the scapement-wheel; when one of these slips off the teeth, and the axle is set free, the spring recoils, and delivers the other pallet into the succeeding notch: and thus the regular motion of the spring, without stopping the revolution of the scapement, regulates the time in which the teeth are let loose, and by this means equalizes the motion of all the wheels.



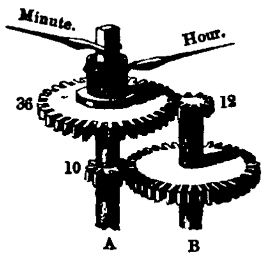
Here is another form of the scapement-wheel. Call the upper part the *crutch,* the lower the *scapement-wheel.* The sustaining force, which, in this instance, is the spring, operating through a succession of wheels, throws out the pallet of the crutch from the tooth of the scapement: in doing this the teeth act against a hair spring, which, by its recoil, places the pallet in the succeeding notch. By this contrivance the regular motion of the hair spring corrects the lesser deviation in the motion of the wheels which might otherwise arise from the imperfection of the workmanship. The balance-wheel and spring move with a quickness which permits the scapement-wheel to beat 18,000 times in an hour—the common rate of a watch that shows seconds.

Having seen how the motions are regulated, we may consider the rate of revolution in the wheels, according to the number of leaves in the pinions, or of the teeth in the circumference of the wheels. The central wheel, A, that which is moved by the fusee, has sixty-four teeth; these fall into the pinion of the third wheel, B, which has eight leaves, the wheel itself having sixty teeth; these sixty teeth play into the pinion of the fourth wheel, C, which has eight leaves. The central wheel going round once in the hour, the fourth wheel will go round sixty times in an hour, and with the hand attached to its axle it will mark seconds.



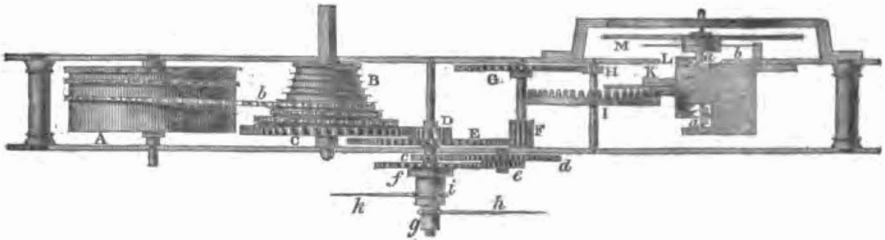
This will be more easily understood by a reference to the sketch. The wheel on the axis, A, to which the minute-hand is attached, turns round once in an hour. Its sixty-four teeth play upon the pinion on the axle, B; as this has eight leaves it will revolve once for every eight teeth of A, and consequently eight times during the whole revolution of A, that is, in an hour. The wheel on the same axle, B, has sixty teeth, which turn the eight-leafed pinion of C; it will, therefore, turn the axle, C, seven times and a half (for $60 \div 8 = 7\frac{1}{2}$) during one revolution, or sixty times during the eight revolutions which B makes in one hour.

Thus we have the minute-hand and the second-hand measuring minutes and seconds of time on the dial; but we have not yet the hand which shall go round in twelve hours and mark the hours on the dial. To effect this the same machinery is used: viz., the wheel and pinion; but the moving power is applied so as to diminish the rate of motion—that is, by making the force act from the leaves of the pinions to the teeth of the wheels, instead of from the teeth to the leaves.



We may remember that the centre wheel, A, goes round once in an hour; that the axle of this wheel passes through the dial and has the minute-hand attached to it. The pinion of this wheel, called the *cannon pinion,* has ten leaves, which play, during the hour, upon a wheel, B, having forty teeth, which accordingly is moved round only once in four hours. This wheel, B, has a pinion of twelve leaves working into a wheel of thirty-six teeth, and must therefore make three revolutions to cause that to revolve once. But as the former, B, requires four hours for one revolution, it must occupy twelve in making three: and consequently the thirty-six toothed wheel will take twelve hours to complete one. To its axle, therefore, the index is attached, which we call the hour-hand of the watch. The axle is a cylinder which incloses the axle of the minute-hand, so that both revolve, indicating the hours and minutes on the same circle of the dial.

It has taken some hundred years to perfect a common time-piece, and the account of the successive improvements is very curious.



Description of the Engraving.

A, the barrel; B, the fusee; *b*, a flexible steel chain which communicates the motion of the barrel to the fusee; C, the great wheel; D, the pinion (called the cannon pinion) of the second or centre wheel, designed to revolve once in an hour; E, the centre wheel, containing sixty-four teeth; F, pinion of the third wheel, containing eight leaves; G, third wheel containing sixty teeth; H, pinion of fourth wheel containing eight leaves; I, fourth wheel containing sixty teeth; K, pinion of the balance wheel (sometimes called the scapement wheel) containing six leaves; L, the balance wheel, containing fifteen teeth, which operate upon the pallets of the balance, and give to it its oscillating motion; *a a*, the pallets; M, the balance; *b*, the hair spring; *c d e f*, minute wheels; *c*, pinion of ten teeth revolving once in an hour; *d*, wheel of forty teeth revolving once in four hours; *e*, pinion of twelve leaves; *f*, wheel of thirty-six teeth revolving once in twelve hours; *g*, the end of the axis of the centre wheel upon which the minute hand *h* revolves; *i*, the axis of the hour wheel upon which the hour hand goes round once in twelve hours.

In conclusion, we perceive the dependence of the wheels of a watch upon each other; they are nothing singly; they have no energy inherent in them. In the animal frame it is otherwise; each distinct portion has a quality belonging to it, which stands in relation to the quality of some other part.

Were any property different from that of form, which gives the mechanical power, possessed by part of the watch, it might derange the movements. It would be foolish to imagine any endowment like that of life, but we may suppose some such property as polarization, or magnetism, added to a wheel or lever: what could result but disturbance of the mechanical adjustment? We take the following felicitous example:—

A watchmaker had put into his hands a timepiece; but notwithstanding the excellence of the workmanship, it went irregularly. He took the work to pieces and put it together twenty times: no defect could be discovered, and yet it was imperfect,—it was a bad watch! At last, it occurred to him that the defect must be in the balance-wheel, (which we have seen to be the regulator of the watch); he thought it possible that this part had become magnetized, and on applying a needle to it he found his suspicion true. By coming accidentally into contact with a magnet, the metal of the balance-wheel had acquired an attraction for the steel work of the watch. A property, superadded to a part of the watch, and at variance with the principle of mechanics on which the machinery was constructed, thus deranged the whole.*

* We have taken the illustration from Cecil's 'Remains,' as quoted by Dr. Latham in his Lectures. The author uses it to explain the effect of a certain bias or predilection in the mind, which deranges the otherwise sound reasoning.

END OF THE SECOND VOLUME.

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