LECTURE X.

ON THE PRINCIPLE OF LIFE, IRRITABILITY, AND MUSCULAR POWER.

We have distinguished organic from inorganic matter; and have characterized the former, among other differences, by its being actuated in every separate form by an internal principle, and possessed of parts mutually dependent and contributory to each other's functions. What then is this internal principle,—this wonderful and ever active power, which, in some sort or other, equally pervades animals and vegetables—which extends from man to brutes, from brutes to zoophytes, from zoophytes to fucuses and confervas, the lowest tribes of the vegetable kingdom, whose general laws and phenomena constituted the subject of our last study,—this fleeting and evanescent energy, which, unseen, by the eye, untracked by the understanding, is only known, like its great Author, by its effects; but which, like him too, wherever it winds its career, is perpetually diffusing around it life and health, and harmony and happiness?

I do not here enter into the consideration of a thinking or intelligent principle, or even a principle of sensation, both which are altogether of distinct natures from the present, and to which I shall entreat your attention hereafter; but confine myself entirely to that inferior but energetic power upon which the identity and individuality of the being depend, and upon a failure of which the individual frame ceases, the organs lose their relative connexion, the laws of chemistry, which have hitherto been controlled by its superior authority, assume their action, and the whole system becomes decomposed and resolved into its primary elements.

The subject is, indeed, recondite, but it is deeply interesting: it has occupied the attention of the wisest and the best of mankind in all ages; and though, after the fruitless efforts with which such characters have hitherto pursued it, I have not the vanity to conceive that I shall be able to throw upon it any thing like perfect daylight, you will not, I presume, be displeased with my submitting to you a brief outline of some few of the speculations to which it has given birth, together with the conjectures it has excited in my own mind.

Of the innumerable theories that have been started upon this subject, the three following are those which are chiefly entitled to our attention. Life is the result of a general harmony or consent of action between the different organs of which the vital frame consists.—Life is a principle inherent in the blood.—Life is a gas, or aura, communicated to the system from without. Each of these theories has to boast of a very high degree of antiquity; and each, after having had its day, and spent itself, has successively yielded to its rivals; and in its turn has reappeared, under a different modification, in some subsequent age, and run through a new stage of popularity.

For THE SYSTEM OF HARMONY we are indebted to the inventive genius of Aristoxenus, a celebrated physician of Greece, who was at first a pupil of Lamptus of Erythræa, afterward of Xenophylus the Pythagorean, and lastly of Aristotle. He was most excellently skilled in music, and is supposed to have given the name of HARMONY to his system from his attachment to this science. It is an ingenious and elegant dogma, and was at one time highly fashionable at Rome as well as at Athens; and is thus alluded to and explained by Lactantius: "As in musical instruments, an accord and assent of sounds, which musicians term HARMONY, is produced by the due tone of the strings; so in bodies, the faculty of perception proceeds from a connexion and vigour of the members and organs of the frame."*

To this theory there are two objections, either of which is fatal to it. The

* V. 140.

first is, that admitting the absolute necessity of the health or perfection of every separate part to the health or perfection of the whole, we are still as much in the dark as ever in respect to the principle by which this harmonious machine has been developed, and is kept in perpetual play. The second objection, by which, indeed, it was vigorously attacked by the Epicureans, and at length completely driven from the field, is derived from observing that the health or well-being of the general system does not depend upon that of its collective organs; and that some parts are of far more consequence to it than others. Thus the mind, observes Lucretius, in his able refutation of this hypothesis, may be diseased, while the body remains unaffected; or the body, on the contrary, may lose some of its own organs, while the mind, or even the general health of the body itself, continues perfect.

The abbé Polignac, who, consistently with the Cartesian system, makes a very proper distinction between the principle of the mind or soul, and that of the life, enters readily into the hypothesis of Aristoxenus in regard to the latter power, though he thinks it inapplicable to the former: and Leibnitz appears to have availed himself of it as a means of accounting for the union between the soul and body in his celebrated system, which he seems to have named, from the theory before us, the system of PRE-ESTABLISHED HARMONY. By a writer of the present day, however, M. Lusac, the doctrine of Aristoxenus seems to have been resuscitated in its fullest scope, and even to have been carried to a much wider latitude than its inventor had ever intended: for the theory of M. Lusac affects to regard, not only the frame of man and other animals, but the vast frame of the universe, as a sort of musical organ or instrument; the concordant and accumulated action of whose different parts or agents he denominates, like Aristoxenus, *harmony*. "Concerts of music," says he, "afford a clear example: you perceive harmony in music when different tones, obtained by the touch of various instruments, excite one general sound, a compound of the whole." This observation he applies to the grand operations of nature, the irregularities of which, resulting from inundations, earthquakes, volcanoes, tempests, and similar evils, this philosopher considers as the dissonances occasionally introduced into music to heighten the harmony of the entire system. With respect to the harmony of the human frame, individually contemplated, or the concordant action of the different parts of the body, he observes, "It may be said, that of this principle I have merely a confused notion; and I admit it, if the assertion imply that I have neither a perfect nor a distinct, nor an entire comprehension of what produces this harmony—in what it consists, or how it acts. I know not what produces the harmony of various instruments heard simultaneously; but I can accurately distinguish the sounds which are occasioned when musicians are *tuning*, from those which are produced when, being completely in tune, and every one uniting in the piece, the separate parts are executed with precision. When I hear an harmonious sound, whatever be its nature, I can distinguish the harmony, though incapable of investigating its cause."*

I shall only observe, farther, that in the doctrine of Mr. (now Sir Humphry) Davy, which holds life itself as a perpetual series of corpuscular changes, and the substrate, or living body, as the being in which these changes take place, we cannot but observe a leaning towards the same system; and we shall have occasion, in a subsequent lecture, to notice one or two others of equally modern date that touch closely upon it in a few points.†

Let us pass on, then, to a consideration of the second hypothesis I have noticed, and which consists in regarding THE BLOOD ITSELF AS THE PRINCIPLE OF LIFE. This opinion lays claim to a still higher antiquity than the preceding; and, in a general view of the question, is far better founded. It has the fullest support of the Mosaic writings, which expressly appeal to the doctrine, that "the life of all flesh is the blood thereof,"‡ as a basis for the culi-

* Du Droit Naturel, Civil, et Politique, tom. i. 154. † Series III. Lecture V.
‡ Levit. xvii. 14.

nary section of the Levitical code; a doctrine, indeed, of no new invention, even at that early period, but probably derived expressly from the ritual of the higher patriarchs, if we may be allowed to appeal to a similar belief and a similar practice among the Parsees, Hindoos, and other oriental nations of very remote antiquity, who seem rather to have drawn this part of their ceremonial directly from the law or tradition of the patriarchs, than indirectly from that of the Jews.

Among the Greeks and Romans, were the authority of the poets to be of any avail, we should imagine that this hypothesis never ceased to be in reputation: for the πορφύρεος θάνατος, or *purple death*, of Homer, and the *purpurea anima*, or *purple life*, of Virgil (phrases evidently derived from this theory), are commonplace terms amid all of them: but the real fact is, that among the philosophers, we do not know of more than two, Empedocles and Critias, who may be fairly said to have embraced it.

In modern times, however, this hypothesis has again dawned forth, and risen even to meridian splendour, under auspices that entitle it to our most attentive consideration. Harvey, to whom we are indebted for a full knowledge of the circulation of the blood, may be regarded as the phosphor of its uprising; Hoffman speedily became a convert to the revived doctrine; Huxham not only adopted it, but pursued it with so much ardour, as, in his own belief, to trace the immediate part of the blood in which the principle of life is distinctly seated, and which he supposed to be its red particles. But it is to that accurate and truly original physiologist, Mr. John Hunter, that we can only look for a fair restoration of this system to the favour of the present day, or for its erection upon any thing like a rational basis. By a variety of important experiments, this indefatigable and accurate observer succeeded in proving incontrovertibly that the blood contributes in a far greater degree, not only to the vital action, but to the vital material of the system, than any other constituent part of it, whether fluid or solid. But he went beyond this discovery, and afforded equal proof, not only that the blood is a means of life to every other part, but that it is actually alive itself. "The difficulty," says he, "of conceiving that the blood is endowed with life, while circulating, arises merely from its being a fluid, and the mind not being accustomed to the idea of a living fluid.—I shall endeavour," he continues, "to show that organization and life do not in the least depend upon each other; that organization may arise out of living parts and produce action, but that life can never arise out of or produce organization."*

This is a bold speculation, and some part of it is advanced too hastily: for instead of its being true, "that life can never arise out of or produce organization," the most cursory glance into nature will be sufficient to convince every man that organization is the ordinary, perhaps the only, means by which life is transmitted; and that wherever life appears, its tendency, if not its actual result, is nothing else than organization. But though he failed in his reasoning, he completely succeeded in his facts, and abundantly proved that the blood itself, though a fluid and in a state of circulation, is actually endowed with life: for he proved, first, that it is capable of being acted upon and contracting, like the solid muscular fibre, upon the application of a stimulus; of which every one has an instance in that cake or coagulum into which the blood contracts itself when drawn from the arm, probably in consequence of the stimulus of the atmosphere. He proved, next, that in all degrees of atmospherical temperature whatever, whether of heat or cold, which the body is capable of enduring, it preserves an equality in its own temperature; and in addition to this very curious phenomenon, he proved also, that a new-laid egg, the vessels of which are merely in a nascent state, has a power of preserving its proper temperature, and of resisting cold, heat, or putrefaction, for a considerable period longer than an egg that has been frozen, or in any other way deprived of its vital principle. Thirdly, he proved, in the instance of paralytic limbs, that the blood is capable of preserving vitality when every

* Hunter on the Blood, p. 20.

other part of an organ has lost its vital power, and is the only cause of its not becoming corrupt. Fourthly, that though not vascular itself, it is capable, by its own energy, of producing new vessels out of its own substance, and vessels of every description, as lymphatics, arteries, veins, and even nerves.* Finally, he proved, that the blood, when in a state of health, is not only, like the muscular fibre, capable of contracting upon the application of a certain degree of appropriate stimulus, but that, like the muscular fibre also, it is instantly exhausted of its vital power whenever such stimulus is excessive; and that the same stroke of lightning that destroys the muscular fibre, and leaves it flaccid and uncontracted, destroys the blood, and leaves it loose and uncoagulated.

Important, however, as these facts are, they do not reach home to the question before us. They sufficiently establish the blood to be alive, but they do not tell us what it is that makes it alive: on the contrary, they rather drive us into a pursuit after some foreign and superadded principle; for that which is at one time alive, and at another time dead, cannot be life itself.

The next theory, therefore, to which I have adverted, undertakes to explain in what this foreign and superadded principle consists. SOME EXQUISITELY SUBTLE GAS OR AURA—some fine, elastic, invisible fluid, sublimed by nature in the deepest and most unapproachable recesses of her laboratory, and spirited with the most active of her energies. An approach towards this hypothesis is also of great antiquity; for it constituted one of the leading features of the Epicurean philosophy, and is curiously developed by Lucretius in his poem on the Nature of Things. According to him, it is a gas or aura, for which in his day there was no name, diffused through every part of the living fabric, swifter and more attenuate than heat, air, or vapour, with all which it concurs in forming the soul or mind as its chief elementary principle:—

> Far from all vision this profoundly lurks,
> Through the whole system's utmost depth diffus'd,
> And lives as soul of e'en the soul itself.†

But it is to the astonishing discoveries of modern chemistry alone that we are indebted for any fair application of any such fluid to account for the phenomena of life.

Among the numerous gases which modern chemistry has detected, there are three which are pre-eminently entitled to our attention, though they seem to have been glanced at by the Epicureans: caloric, or the matter of heat, chiefly characterized in our own day as a distinct substance, by the labours of Dr. Black and Dr. Crawford; oxygen, or the vital part of atmospheric air, first discovered by Priestly, and explained by Lavoisier; and the fluid which is collected by the Voltaic trough, and which is probably nothing more than the electric fluid under a peculiar form.

Of these, caloric, as a distinct entity, was detected first. It was found to be a gas of most astonishing energy and activity, and, at the same time, to be of the utmost consequence to the living substance; to exist manifestly wherever life exists, and to disappear on its cessation. It was hence conceived to be the principle of life itself.

But oxygen began now to start into notice, and the curious and indispensable part it performs in the respiration, as well as in various other functions of both animal and vegetable existence, to be minutely explored and ascertained, and especially by the microscopic eye of M. Girtanner.‡ The genius of Crawford fell prostrate before that of Lavoisier. Oxygen was now regarded as the principle of life, and heat as its mere attendant or handmaid.

About the year 1790, Professor Galvani, of Bologna, accidentally discovered

* Dr. Munro has proved, that the limb of a frog can live and be nourished, and its wounds heal, without any nerve.

> † Nam penitus prorsum latet hæc natura, subestque;
> Nec magis hac infra quidquam est in corpore nostro;
> Atque anima est animæ proporro totius ipsa.
> De Rer. Nat. iii. 274.

‡ Mèmoires sur l'Irritabilité, considerée comme principe de vie dans la nature organisée. Paris, 1790.

that the crural nerve of a frog, which had been cut up for his dinner, contracted and became convulsed on the application of a knife wetted with water; and following* up this simple fact, he soon discovered also, that a similar kind of contraction or convulsion might be produced in the muscles of other animals, when in like manner prepared for the experiment, not only during life, but for a considerable period after death; and that in all such cases a fluid of some sort or other was either given to the contracting body or taken from it. And Professor Volta, about the same period, succeeded in proving that the fluid thus traced to be given or received was a true electric aura; that it might, in like manner, be obtained by a pile of metallic plates, of two or three different kinds, separated from each other by water, or wetted cloth or wadding; and be so accumulated by a multiplication of such plates, as to produce the most powerful agency in all chemistry. It is not necessary to pursue this subject any farther. Every one in the present day has some knowledge of Galvanism and Voltaism; every one has witnessed some of those curious and astonishing effects which the Voltaic fluid is capable of operating on the muscles of an animal for many hours after death: and it only remains to be added, that since the discovery of this extraordinary power, oxygen has in its turn fallen a sacrifice to the Voltaic fluid, and this last has been contemplated by numerous physiologists as constituting the principle of life; as a fluid received into the animal system from without, and stimulating its different organs into vital action. "The identity," says Dr. Wilson Phillip, "of Galvanic electricity and nervous influence is established by these experiments."

The result of the whole appears to be, that neither physiology nor chemistry, with all the accuracy and assiduity with which these sciences have been pursued of late years, has been able to arrest or develope the fugitive principle of life. They have unfolded to us the means by which life, perhaps, is produced and maintained in the animal frame, but they have given us no information as to the thing itself; we behold the instrument before us, and see something of the fingers that play upon it, but we know nothing whatever of the mysterious essence that dwells in the vital tubes, and constitutes the vital harmony.

It seems to be on this account, chiefly, that the existence of such a principle as a substantive essence has been of late years denied by MM. Dumas, Bichat, Richerand, Magendie, and, indeed, most of the physiologists of France; whose hypothesis has been caught up and pretty widely circulated in our own country, as though nothing in natural science can be a fair doctrine of belief, unless its subject be matter of clear developement and explanation. But this uncalled-for skepticism has involved these philosophers in a dilemma from which it seems impossible for them to extricate themselves, and which we shall have occasion to notice more fully hereafter: I mean the existence of powers and faculties without an entity or substantial base to which they belong, and from which they originate. They allow themselves to employ the term, and cannot, indeed, do without it; but after all they mean nothing by it. "No one in the present day," says M. Richerand, "contests the EXISTENCE OF A PRINCIPLE OF LIFE, which subjects the beings who enjoy it to an order of laws different from those which are obeyed by inanimate beings; by means of which, among its principal characteristics, the bodies which IT ANIMATES are withdrawn from the absolute government of chemical affinities, and are capable of maintaining their temperature at a near degree of equality, whatever be that of the surrounding atmosphere. Its ESSENCE is not designed to preserve the aggregation of constituent molecules, but to collect other molecules which, by assimilating themselves to the organs that IT VIVIFIES, may replace those which daily losses carry off, and which are employed in

* It is a singular fact, that this identical discovery was not only made, but completed in all its bearings, and by the same means of a recently-dissected frog, by Dr. Alexander Stuart, physician to the queen, in 1732, though no advantage was taken of it. A minute account of Dr. Stewart's experiments is given in the Phil. Trans. for 1732. See the author's Study of Medicine, vol. iii. p. 29, 2d edit.

repairing and augmenting them."* Yet, when we come to examine into the subject more closely, we find that all these terms, so expressive of a specific being and distinct reality—this ESSENCE that VIVIFIES and ANIMATES, has neither being, nor essence, nor vivification, nor animation, nor reality of any kind; that the whole of these expressions are metaphysical; and that the word VITAL PRINCIPLE is not designed to express a distinct being, but is merely an abridged formula, denoting the TOTALITY OF POWERS ALONE which animate living bodies, and distinguish them from inert matter, the TOTALITY OF PROPERTIES and LAWS which govern the animal economy.† So that we have here not only the employment of terms that have no meaning, but properties and laws, powers and principles, without any source,—a superstructure without a foundation,—effects without a cause.

But what is this curious and delicate instrument itself?—this machine that so nicely responds to the impressions communicated to it, and visibly envelopes so invisible a constituent?

It is not my intention in this series of popular study to enter into any minute history of the animal frame, but shall confine myself to those general views of it which are requisite to show by what means it is operated upon by the delicate powers we have just contemplated, and the more curious phenomena which result from such an impulse.

The animal frame, then, is a combination of living solids and fluids, duly harmonized, and equally contributory to each other's perfection. The principle of life, whatever it consists of, exists equally in both; in some kinds in a greater, in others in a less degree. In the fluids, Mr. Hunter has traced it down to their first and lowest stage of existence, for he has traced it in the chyle;‡ and there are evident proofs of its accompanying several of those which are eliminated from the body; in the blood it is found, as we have already had occasion to notice, in a high degree of activity, and probably in a still higher in the nervous fluid.

In the solids it varies equally. There are some in which it can scarcely be traced at all, excepting from their increasing growth, as the cellular membrane, and the bones; in others, we find a perpetual internal activity, or susceptibility to external impressions. But it is in those irritable threads or fibres which constitute the general substance of the muscles or flesh of an animal, that the principle of life exerts itself in its most extraordinary manner, and which it more immediately, therefore, falls within the scope of the present lecture to investigate.

The muscle of an animal is a bundle of these irritable fibres, or soft, red, cylindrical, and nearly inelastic threads, formed out of a substance which the chemists, from the use to which it is applied, denominate fibrine; and which, when examined microscopically, are seen to divide and subdivide, as far as the power of glasses will carry the eye, into minuter bundles of fibrils, or still smaller threads, parallel to each other, and bound together by a delicate cellular web-work, obviously of a different nature. They are uniformly accompanied through their course by a number of very minute nerves, which are chords or tubes that originate from the brain, and branch out in every direction, either immediately from the brain itself, or from some part of the spinal marrow, which is a continuation of this organ; by which means a perpetual communication is kept up between the sensorium and the remotest part of the body, as we shall have farther occasion to notice hereafter.§ Upon the

* "Personne aujourd'hui ne conteste l'EXISTENCE D'UN PRINCIPE DE VIE qui soumet les êtres qui en jouissent à un ordre de lois différentes de celles auxquelles obéissent les êtres inanimés, force à laquelle on pourroit assigner, comme principaux caractères, de soustraire les corps qu'ELLE ANIME, à l'empire absolu des affinités chimiques, auxquelles ils auroient tant de tendance à ceder, en virtu de la multiplicité de leurs élémens; et de maintenir leur température à un dégré presque égal, quelle que soit d'ailleurs celle de l'atmosphère. Son ESSENCE n'est point de conserver l'aggregation des molécules constitutives, mais d'attirer d'autres molécules qui, s'assimilant aux organes qu'ELLE VIVIFIE, remplacent celle qu'entraînent les pertes journalières, et sont employées à les nourrir et à les accroître."—Nouveaux Elémens de Physiologie, tom. i. p. 81. Paris, 8vo. 1804.

† "Le mot de PRINCIPE VITAL, force vitale, &c. n'exprime point un être existant par lui-même, et indépendamment des actions par lesquelles il se manifeste: il ne faut l'employer que comme une formule abrégée dont on se sert pour désigner l'ensemble des forces qui animent les corps vivans et les distinguent de la matière inerte:—l'ensemble des propriétés et des loix qui régissent l'économie animale."—Ib. p. 80.

‡ On the Blood, p. 91.

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application of any irritating or stimulating power, these fibres immediately contract in their length, and upon the cessation of such power return to their former state of relaxation: and it is chiefly by this curious contrivance that the animal system is enabled to fulfil all its functions. The stimuli by which the fibres, whether of motion or of sensation, are roused into action, are perhaps innumerable in the whole; but a few general classes may easily be devised to comprise all those by which they are ordinarily affected. And while by an admirable diversity of construction, some sets of fibres are only affected by some sets of stimuli, other sets are only affected by others; and in this manner all the organs are compelled, as it were, to execute the different offices intrusted to them, and no one interferes with that of another. Thus the fibres of the external senses are affected by external objects; they contract and give notice of the presence and degree of power of such objects to the brain, through the medium of the nerves, which, as I have just observed, always accompany them, and which either terminate in or arise from that organ: but while the irritative and sensitive fibres of the ear are excited only by the stimulus of sound, and have no impression produced upon them by that of light, those of the eye are excited only by the stimulus of light, and remain uninfluenced by that of sound: and so of the other organs of external sense. And hence we obtain a knowledge of one set or class of stimuli, which from their acting upon the organs of sense, are called sensitive stimuli, and the motions to which they give rise sensitive motions.

Again, the very substances naturally introduced into many of the muscular organs of the body, and especially the hollow muscles, are sufficient to excite them to a due performance of their functions: thus, the lungs are excited to the act of respiration by the stimulus of the air we breathe, the stomach to that of digestion by the stimulus of the food introduced into it; so the heart and blood-vessels are excited by the stimulus of the blood; and the vessels that carry off the recremental materials by the different stimuli which these materials contain in themselves. We hence obtain another class of stimuli, which are denominated stimuli of simple irritation; and the motions they produce, simple irritative motions, or motions of irritation.

But the sensory, or brain, which thus receives notice generally, or is impressed upon by the different actions that are perpetually taking place all over the system, through the medium of its own ramifications, or nerves, that uniformly acccompany the irritable fibres, in many instances originatês motions, and thus proves a stimulus in itself. All voluntary motions are of this kind; the will, which is a faculty of the sensorium, being the exciting cause, and thus giving birth to a third class of stimuli, and of a very extensive range, which are called stimuli of volition. While habit or association becomes, in a variety of instances, a sufficient impulse to other motions, and thus constitutes a fourth class; which are hence named associate stimuli, or stimuli of association.

But though the muscular fibre is, perhaps, more irritable than any other part of the system, the principle of irritability and a fibrous structure are by no means necessarily connected; for, while the cellular membrane is fibrous but has no irritability whatever, the skin is not fibrous but is highly irritable.

Hence solids and fluids are equally necessary to the perfection of the living system. Food, air, and the ethereal gases, caloric, oxygen, and the medium of electricity, are the stimuli by which it is chiefly excited to action; and, by their combination, contribute in some degree to the matter of the system itself; but of the mysterious power that developes the organs and applies the stimuli, that harmonizes the action and constitutes the life, we know nothing.

We see clearly, however, that the moving powers are, for the most part, the muscles; and it is a subject of perpetual astonishment to the physiologist to observe the prodigious force which these vital cords are made capable of exerting, and the infinite variety of purposes to which they thus become subservient. And were it not that the whole universe swarms with proofs of intelligence and design—were it not that there exists, to adopt the beautiful words of the poet—

> Books in the running brooks,
> Sermons in stones, and good in every thing—

this, perhaps, might be the part of creation which we could best select in proof of the wisdom of the Creator.

It was formerly too much the custom to regard the animal frame as a mere mechanical machine; whence, in that spirit of absurdity with which the wisest of mankind are occasionally afflicted, Descartes affected to believe that brutes are as destitute of consciousness as a block of wood, and that it is exactly the same sort of necessity which drives a dog forward in pursuit of a hare, that compels the different pipes of an organ to give forth different tones upon a pressure of the fingers against its different keys. It is not every one, however, in modern times who has adopted the mechanical theory that has carried it to this extremity of absurdity; but all of them are still carrying it too far who reason concerning the principal motions of the body as mere mechanical motions, and the powers which the muscles exert as mere mechanical powers; in which the bones are the levers, the joints the fulcra, and the muscles the moving cords; for it so happens that all the effects for which the whole of this complicated machinery is absolutely necessary out of the body, are in many instances performed by a single part of it within the body, namely, by the moving cords or muscles alone, without either bones or joints, levers or fulcra. I do not mean to contend that there is no kind of resemblance or conformity of principle between the laws of animate and inanimate mechanics, for I well know that in a variety of points the two systems very closely concur; but I am obliged to contend that they are still two distinct systems, and that in the one case the living power exercises an influence which finds no sort of similitude in the other.

It is, indeed, curious to observe the difference of result which has flowed from the calculations of the different promoters of this theory; and which alone, were there nothing else to oppose them, would be sufficient to prove the fallacy of their reasoning. Among those who have adopted this mode of explanation, and have pursued it with most acuteness, and may be regarded as the fathers of the school, I may be allowed to mention Borelli and Keil; but while the former, in order to account for the circulation of the blood in man, calculated the force with which the heart contracts to be equal to not less than a hundred and eighty thousand pounds weight at every contraction, the latter could not estimate it at more than eight ounces.

In like manner Borelli, in applying the same theory to the power with which the human stomach triturates, or, as we now call it, digests its food, calculated it, in conjunction with the assistance it receives from the auxiliary muscles, which he conceived to divide the labour about equally with itself, as equal to two hundred and sixty-one thousand one hundred and eighty-six pounds; and Pitcairn has made it very little less, since he estimates the moiety contributed by the stomach alone at one hundred and seventeen thousand and eighty-eight pounds; which gives to these organs jointly a force more than equal to that of twenty mill-stones! "Had he," says Dr. Munro, "assigned five ounces as the weight of the stomach, he had been nearer the truth."*

The fallacy of this theory, however, and especially as it applies to the stomach, has been completely exposed in our own day, by the well-ascertained fact, that though the muscular coat of the stomach in most animals bears some part in the process of digestion, this important operation is almost entirely performed by a powerful chemical solvent secreted by the stomach itself for this very purpose, and hence denominated the gastric juice; and which answers all the purposes of the most violent muscular pressure we can conceive, and with a curious simplicity of contrivance.

The laws of physical force will certainly better apply to the action of the heart and arteries than to that of the stomach, and in some measure assist us

* Comp. Anat. pref. p. viii. note.

in accounting for the circulation of the blood; but the moment we reflect that one-half of this very circulation, that I mean which depends upon the veins, and which has for the most part to contend against the attraction of gravitation, instead of being able to avail itself of its assistance, is produced without any muscular propulsion that we are able to discover, and that even the arteries do not, when uninfluenced by pressure, appear to change their diameter in a state of health,* we are necessarily driven to the conclusion, that there is in animal statics, as well as in animal mechanics, a something distinct and independent, and which the laws of physical force are altogether incompetent to explain. Dr. Young, in his excellent Croonian lecture, read before the Royal Society in 1809,† has endeavoured to revive the mechanical theory; but he is still compelled to admit a variety of phenomena in the animal machine, and especially in the circulatory system, which are altogether unaccountable upon any of the known principles of common hydraulics, and which can never fail to reduce us to the same result.

So far, therefore, as we at present know, the circulation of the blood is performed by a double projectile power; one moiety being dependent on the action of the living principle in the heart, and perhaps the arteries; and the other moiety on the common law of hydraulics, or the vacuum produced in the heart by that very contraction or systole which has just propelled the blood returned from the lungs into the arterial system. Whence the heart itself becomes alternately a forcing and a suction pump; being the former in respect to the arteries, and the latter in respect to the veins.‡

Upon a moderate estimate, the common labourer may be said to employ a force capable of raising a weight of ten pounds to the height of ten feet in a second, and continued for ten hours a day. A moderate horizontal weight for a strong porter, walking at the rate of three miles an hour, is 200 pounds: the chairman walks four miles an hour, and carries 150 pounds. The daily work of a horse is equal to that of five or six men upon a plane; but from his horizontal figure in drawing up a steep ascent, it does not exceed the power of three or four men. In working windmills, twenty-five square feet of the sails is equivalent to the work of a single labourer; whence a full-sized mill, provided it could be made to work eight hours a day, would be equivalent to the daily labour of thirty-four men. A steam engine of the best construction, with a thirty inch cylinder, has the force of forty horses; and as it acts without intermission, will perform the work of 120 horses, or of 600 men; every square inch of the piston being equivalent to the power of a labourer.

There are many muscles given to us which the common customs and habits of life seldom render it necessary to exert, and which in consequence grow stiff and immoveable. Tumblers and buffoons are well aware of this fact; and it is principally by a cultivation of these neglected muscles that they are able to assume those outrageous postures and grimaces, and exhibit those feats of agility, which so often amuse or surprise us.

The same muscles of different persons, however, though of the same length and thickness, and, so far as we are able to trace, composed of the same number of fibres, are by no means uniformly possessed of the same degree of power; and we here meet with an express deviation from the law of physical mechanics; as we do also in the curious fact, that whatever be the power they possess, they grow stronger in proportion to their being used, provided they are well used, and not exhausted by violence or over-exertion.

I have calculated the average weight carried by a stout porter in this metropolis at 200 pounds; but we are told there are porters in Turkey, who by accustoming themselves to this kind of burden from an early period, are able to carry from 700 to 900 pounds, though they walk at a slower rate, and only carry the burden a short distance. "The weakest man can lift with his hands about 125 pounds, a strong man 400. Topham, a carpenter, mentioned by Desaguliers, could lift 800 pounds. He rolled up a strong pewter dish with his fingers. He lifted with his teeth and knees a table six feet long, with a half hundred weight at the end. He bent a poker, three inches in circumference, to a right angle, by striking it upon his left forearm; another he bent and unbent about his neck, and snapped a hempen rope two inches in circumference. A few years ago there was a person at Oxford who could hold his arm extended for half a minute, with half a hundred weight hanging on his little finger."* We are also told by Desaguliers of a man who, by bending his body into an arch, and having a harness fitted to his hips, was capable of sustaining a cannon weighing two or three thousand pounds. And not many winters ago, the celebrated Belzoni, when first entering on public life, exhibited himself to the theatres of this metropolis, and by a similar kind of harnessing was capable of supporting, even in an upright position, a pyramid of ten or twelve men surmounted by two or three children, whose aggregate weight could not be much less than 2000 pounds; with which weight he walked repeatedly towards the front of the stage.

* See Lect. VIII p. 91, as also the Author's Study of Medicine, vol. ii. p. 16. Edit. 2d, 1825.
† On the Functions of the Heart and Arteries, Phil. Trans. 1809, p. 1.
‡ See Study of Med. vol. ii. p. 19. Ed. 2d.

The prodigious powers thus exerted by human muscles will lead us to behold with less surprise the proofs of far superior powers exerted by the muscles of other animals, though it will by no means lead us to the means of accounting for such facts.

The elephant, which may be contemplated as a huge concentration of animal excellencies, is capable of carrying with ease a burden of between three and four thousand pounds. With its stupendous trunk (which has been calculated by Cuvier to consist of upwards of thirty thousand distinct muscles) it snaps off the stoutest branches from the stoutest trees, and tears up the trees themselves with its tusks. How accumulated the power that is lodged in the muscles of the lion! With a single stroke of his paw he breaks the backbone of a horse, and runs off with a buffalo in his jaws at full speed: he crushes the bones between his teeth, and swallows them as a part of his food.

Nor is it necessary, in the mystery of the animal economy, that the muscles should always have the benefit of a bony lever. The tail of the whale is merely muscular and ligamentous; and yet this is the instrument of its chief and most powerful attack; and, possessed of this instrument, to adopt the language of an old and accurate observer,† "a long-boat he valueth no more than dust, for he can beat it all in shatters at a blow." The skeleton of the shark is entirely cartilaginous, and totally destitute of proper bone; yet is it the most dreadful tyrant of the ocean: it devours with its cartilaginous jaws whatever falls in its way; and in one of its species, the squalus *carcharias*, or white shark, which is often found thirty feet long, and of not less than four thousand pounds weight, has been known to swallow a man whole at a mouthful.

The sepia *octopodia*, or eight-armed cuttlefish—the polypus of Aristotle—is found occasionally of an enormous size in the Mediterranean and Indian seas, its arms being at times nine fathoms in length, and so prodigious in their muscular power, that when lashed round a man, or even a Newfoundland dog, there is great difficulty in extricating themselves; and hence the Indians never venture out without hatchets in their boats, to cut off the animal's holders, should he attempt to fasten on them, and drag them under water.

But this subject would require a large volume, instead of occupying the close of a single lecture. Let us turn from the great to the diminutive. How confounding to the skill of man is the muscular arrangement of the insect class! Minute as is their form, there are innumerable tribes that unite in themselves all the powers of motion that characterize the whole of the other classes; and are able, as their own will directs, to walk, run, leap, swim, or fly, with as much facility as quadrupeds, birds, and fishes exercise these faculties separately. But such a combination of functions demands a more complicated combination of motive powers; and what

* Young's Lect. on Nat. Phil. i. 129.
† Frederick Martens. See Shaw, II. ii. 489.

it demands it receives. In the mere larve or caterpillar of a cossus, or insect approaching to the butterfly, Lyonet has detected not less than four thousand and sixty-one distinct muscles, which is about ten times the number that belong to the whole human body; and yet it is probable that these do not constitute any thing like the number that appertain to the same insect in its perfect state. The elator *noctilucus*, or phosphorescent springer, is a winged insect; but it has also a set of elastic muscles, which enable it, when laid on its back, to spring up nearly half a foot at a bound, in order to recover its position. This insect is also entitled to notice in consequence of its secreting a light, which is so much beyond that of our own glow-worm, that a person may see to read the smallest print by it at midnight. The cicada *spumaria*, or spumous grasshopper, is in like manner endowed with a double power of motion; and when attempted to be caught will either fly completely off, at its option, or bound away at the distance of two or three yards at every leap. This insect is indigenous to our own country, and is one of those which in their larve and pupe states discharge, from the numerous pores about the tail, that frothy material upon plants which is commonly known by the name of cuckow-spit.

Crabs and spiders have a strong muscular power of throwing off an entire limb whenever seized by it, in order to extricate themselves from confinement; and most of them throw off also, once a year, their skin or crustaceous covering, and secrete a new one. The muscular elasticity of the young spider gives it, moreover, the power of wings; whence it is often seen, in the autumn, ascending to a considerable elevation, wafted about by the breeze, and filling the atmosphere with its fine threads. The land-crab (cancer *ruricola*) inhabits the woods and mountains of a country; but its muscular structure enables it to travel once a year to the seacoast to wash off its spawn in the waters. The spawn or eggs thus deposited sink into the sands at the bottom of the sea, and are soon hatched; after which millions of little crabs are seen quitting their native element for a new and untried one, and roving instinctively towards the woodlands.

The hinge of the common oyster is a single muscle; and it is no more than a single muscle in the chama gigas, or great clamp-fish, an animal of the oyster form, but the largest testaceous worm we are acquainted with. It has been taken in the Indian Ocean of a weight not less than 532 pounds; the fish, or inhabitant, being large enough to furnish 120 men with a meal, and strong enough to lop off a hand with ease, and to cut asunder the cable of a large ship.

Nor is the muscular power allotted to the worm tribes less wonderful than that of insects, or its variety less striking and appropriate. The leech and other sucker-worms are as well acquainted with the nature of a vacuum as Torricelli; and move from place to place by alternately converting the muscular disks of their head and tail into air-pumps.

The sucker of the cyclopterus, a genus of fishes denominated suckers from their wonderfully adhesive property, is perhaps the most powerful, for the size of the fish, of any we are acquainted with; and is formed at will, by merely uniting the peculiar muscles of its ventral fins into an oval concavity. In this state, if pulled by the tail, it will raise a pailful of water rather than resign its hold.

The teredo *navalis*, or ship-worm, is seldom six inches in length, but the muscles and armour with which its head is provided enables it to penetrate readily into the stoutest oak planks of a vessel, committing dreadful havoc among her timbers, and chiefly producing the necessity for her being copper-bottomed. This animal is a native of India; it is gregarious, and always commences its attack in innumerable multitudes; every worm, in labouring, confining itself to its own cell, which is divided from that of the next by a partition not thicker than a piece of writing-paper. The seaman, as he beholds the ruin before him, vents his spleen against the little tribes that have produced it, and denounces them as the most mischievous vermin in the ocean. But a tornado arises—the strength of the whirlwind is abroad—the clouds

pour down a deluge over the mountains—and whole forests fall prostrate before its fury. Down rolls the gathering wreck towards the deep, and blocks up the mouth of that very creek the seaman has entered, and where he now finds himself in a state of captivity. How shall he extricate himself from his imprisonment?—an imprisonment as rigid as that of the Baltic in the winter season. But the hosts of the teredo are in motion:—thousands of little augurs are applied to the floating barrier, and attack it in every direction. It is perforated, it is lightened, it becomes weak; it is dispersed, or precipitated to the bottom; and what man could not effect, is the work of a worm. Thus it is that nothing is made in vain; and that in physics, as well as in morals, although evil is intermingled with good, the good ever maintains a predominancy.

LECTURE XI.

ON THE BONES, CARTILAGES, TEETH, ARTICULATION, INTEGUMENTATION, HAIR, WOOL, SILK, FEATHERS, AND OTHER HARD OR SOLID PARTS OF THE ANIMAL FRAME.

In a former lecture we took a general survey of the characteristic features that distinguish the unorganized from the organized world, and the vegetable kingdom from the animal: we examined into the nice structure of plants, and the resemblances which they bear to the animated form. In our last lecture we proceeded to an inquiry into the nature of the living principle, took a glance at a few of the theories that have been invented to explain its essence and mode of operation, and contemplated the origin and powers of the muscular fibre, which may be denominated its grand executive organ.

The muscles of an animal, however, are not the only instruments of animal motion; the bones, cartilages, and ligaments contribute very largely to the action, and the skin is not unfrequently a substitute for the muscle itself. These, therefore, as well as a variety of other bodies minutely connected with them, or evincing a similarity of construction,—as the teeth, hair, nails, horns, shells, and membranes,—are now to pass under our review, and are entitled to our closest attention; and I may add, that their diversity of uses and operations, and the curious phenomena to which they give rise, are calculated to afford not less amusement than instruction.

I had occasion to remark lately,* that lime is a substance absolutely necessary to the growth of man. It is, in truth, absolutely necessary to the growth of almost all animals; even soft-bodied or molluscous worms, except in a few instances, are not free from it; nay, even infusory animals, so minute as to be only discerned by the microscope, still afford a trace of it in the calcareous speck which constitutes their snout; but it is in the bones and shells of animals that lime is chiefly to be found; and hence those animals possess most of it in whom these organs are most abundant.

Bone, shell, cartilage, and membrane, however, in their nascent state, are all the same substance, and originate from a viscid fluid, usually supposed to be the coagulable lymph, or more liquid part of the blood; which, secreted in one manner, constitutes jelly, or gelatine, a material characterized by its solubility in warm water, heated to about half the boiling point; and secreted in another manner, forms albumen, or the material of the white of the egg, characterized by its coagulating instead of dissolving in about the same heat: the difference, however, between the two, consisting merely, perhaps, in the different proportion of oxygen they contain. Membrane, is gelatin, with a small proportion of albumen to give it a certain degree of solidity; cartilage

* Series I. Lect. vi. On Geology, p. 73, and passim; and Lect. viii. On Organized Bodies, and the Structure of Plants compared to that of Animals, p. 81.