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CHARACTERISTICS OF PHYSICAL LIFE.

Protoplasm; or, Matter and Life. By Lionel S. Beale, M.B., F.R.S.

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As regards Protoplasm, in relation to Professor Huxley's Physical Basis of Life. By J. Hutchison Stirling, F.R.C.S.

THERE is perhaps in nature nothing so evident as life, and yet under certain aspects there is perhaps nothing so mysterious. It forms the boundary line between the animate and inanimate kingdoms, and fills earth, air, and sea with its manifold products. With all the cunning of perfect design, and according to the laws given to it, it adapts plants and animals to different countries; under the tropical sun it spreads out its wide-leaved evergreens; in northern climates it strips trees of their foliage or binds them compactly, that they may be able to stand the winter's storm. It is this germinal principle of life which gives its bloom to the rose and its brilliant whiteness to the lily; which scatters variety in every degree of its development in the vegetable kingdom, from the lichen which seems to be identified with the rock over which it creeps, to those "mammoth trees" that rise like so many cathedral spires in the Yosemite valley.

And still this vital principle of growth manifested in such profusion through the vegetative half of the world of life is something which has all along evaded the analytical search of the physicist. He has had at his command carbon, oxygen, hydrogen, and nitrogen elements, which enter essentially into the composition of plants, but manipulate them as he would he has not been able to form

from them even the lowest living organism. Out of them and other elements, indeed, chemical combinations have been made; oxygen and hydrogen have been so combined as to form water; carbon and oxygen have been so mixed as to produce carbonic acid; in the laboratory have also been formed butyric ether and the flavoring juice of the pineapple, as well as the formic acid produced by ants, but all these, though existing as chemical compounds, are not capable by themselves of forming one living cell or tissue. Let it be even granted that science has mastered the inorganic elements and juices that compose any living thing; that it has discovered the variety and combination of its forces, and still it must be admitted that it has not succeeded in making one living compound, nor thoroughly accounted for the results of the constituent elements of any organic or inorganic body. Physical science deals only with sensible facts or phenomena and the laws that govern them, but the ultimate reasons of all these, their substantial support or their cause, it can neither see with the microscope, nor touch with the scalpel. "It is in strictness true," says Mr. Huxley, "that we know nothing about the composition of any body as it is." The scientist can with wonderful precision classify plants and animals according to their species; he can also trace the formation and adaptation of their organs for special functions, but how the lowliest plant grows or how the minutest insect exists, he does not know. The force with which one body attracts another he calls gravitation, but what gravitation is in itself, he is ignorant of. That things live, he is aware of, from the phenomena of life, but what life is in itself, or how precisely it is generated, he cannot by mere physical research determine. Amid the blaze of science, then, in this nineteenth century, at the root of every living thing there still remains mystery.

Elements we know, and laws and phenomena we know, but what is life?

The great characteristic index of life is motion or activity. This is the universal test of animation throughout nature,—the sign by which the dead plant or animal is distinguished from the living. This motion, however, is not barely external or mechanical motion. The locomotive does not live, though it moves, nor is it the attraction of one body for another, as the inertness of the very bodies proves, but it is that principle of activity within a plant or an animal which makes them to live and to grow and to be organized. This is a fact or truth which all animated nature teaches us; every tree of the forest and every plant of the garden proclaim it, as it were, by their freshness and productiveness. Motion or activity thus specified is so indicative of life, so intimately and necessarily related to the principle from which it proceeds, that some scientists

of our time, for their own purposes, seem to say that "life itself is nothing but motion of an infinitely complex kind;" that "it is matter in its finest ferment." They thus confound the phenomena of life with life itself, and taking motion in its generic sense as external motion of one kind or other, they pervert its specific meaning when applied to living things. They tell us that "if matter moves, it is force that moves it," but when they say that "if a certain structure, vegetable or mineral, is produced, it is through the generation of the forces exerted between the atoms and molecules," they assume that the growth of vegetables is the result of the force of attraction—a fact which they have never verified, and which, on the contrary, all observation has shown to be utterly false. Mere material force has never produced and will never produce any living organism. Does magnetic force give life to the iron which the magnet attracts? And since it does not, how can it be said to give the life of growth to the molecules that go to form and to develop the vegetables? Simple attractive force does not surely give any vital energy, otherwise we should have no inert matter and no dead clay, and no one imagines the absurdity that the mechanical force of the lever or screw communicates anything like life to the mass of granite which it raises. Inorganic brute-force, therefore, all experience proves, cannot of itself give vital growth, and the motion which is originated by the same force cannot, consequently, be the index of the principle life. In plants this motion consists in that immanent vital activity whereby their organization is developed and becomes fruitful. In some of their species this activity is so great that by its vegetative force, botanists tell us, it produces the external movement of leaves and branches. "Such movements are not confined to the lowest plants," says a lecturer, "as the Oscillatoriæ, but are met with among the most highly organized members of the vegetable kingdom. The movements of sensitive plants, various species of Mimosæ, of Dionæa muscipula, of certain tropical species of Desmodium, of the stamens of Barberry, etc., can be referred only to the vital contractility of certain of their tissues."

These movements, however, of certain species of plants, do not imply that they have anything like a sensitive nature, that they experience impressions and perceive sensation as animals do. They are influenced by the elements of the atmosphere, by heat and by moisture; to some plants the evening air gives new life, others turn to the sun's heat, while the leaves of others are fatal to the insects that alight upon them. In all these qualities or changes, there is, however, nothing more than the force or quality of vegetative growth, nothing that would indicate a sensible organic nature. Plant life itself excludes such a hypothesis, since it has no sensitive organism, no function which requires sensation, and no movement which is determined or actuated by sense. All nature

proclaims that growth, nutrition, and productiveness are the three special functions of plants. In man himself there exist the qualities of vegetative nature, but no one is conscious that it has the faculties of sensitive life.

Naturalists, it is true, find it difficult to decide whether a few of the lowest of living organisms belong to the vegetable or animal kingdom; and this fact they think, furnishes them with proof for the theory of evolution. Now, strange as it might seem to some, in the same fact, St. Thomas finds reasons for admiring God's wisdom in the exercise of His creative power, in that gradation which He has followed in communicating life to creatures, drawing the dividing line between the vegetable and animal kingdoms, and still making this line so slight that it is hardly perceptible.

But besides those symptoms of life that are seen in certain species of plants, there is the universal law of activity and growth, which reigns in the formation of every herb and tree. It manifests itself in different ways, although indeed the least of the plant's life is that which appears on its surface. Within it, there is going on in its growing season, a never-ceasing movement, a noiseless whirl of various elements, which are assorted, combined, and refined by vital processes in order that they may become fit matter for living tissue. No sooner has the primal cell been formed and the germ been expanded than the budding plant seeks nourishment. On all sides it spreads out its feeders, takes from the soil the food that suits its specific nature, imbibes by its fibrils and roots juices and mineral elements, and takes them into its laboratory, to be there converted into the sap or stuff of life. While this secret feeding is going on from below, another process of nutriment is going on from above. The plant breathes, as it were, through its leaves; through them, under the sun's radiance it retains carbon and releases oxygen, while during night, on the contrary, it retains oxygen and releases carbon. Let a sun-loving plant be kept in the dark, it immediately becomes sickly; it will grow, indeed, but without color or solidity, because it has no carbon to strengthen its digestive powers, to give freshness to its leaves, or firmness to its tissues. The plant dies, but in its specific kind, it lives, as it were, again in its seed. While it exists in vigor, life permeates all its parts, is latent in its minutest cells and tissues, and gives to its organs their special vital functions. From this fact, which is patent to observation, some writers on physiology have concluded that besides the vital forces of a plant or an animal there is no common principle of life in either. In other words, they recognize vital phenomena, but will not admit that they proceed from a principle or cause. Still, surely in this case the arguments from induction and deduction, on which all physical science professes to rest, may be very well applied. On the lines of these arguments, the prin-

ciple of the activity of a living plant seems to be as clearly demonstrable as the existence of the sun from his rays. The plant's vital force manifests itself in countless forms, like so many rays of light working to its ends by fixed laws, giving vegetative growth to each stem or germ, and showing marks of its vivifying influence in leaf and branch, in flowers and fruit—all this it does with a measure and proportion, with a symmetrical growth of the plant, which point distinctly to one controlling principle of activity and life within it. Were its vital energy to act independently of any central directing principle, it might distort nature, turn branches upwards, when it should have turned them downwards, give the shape of a laurel to a pine, or of a palm-tree to an elm. We should then be at a loss to know how their life-fluid is distributed to all the organs of the plant according to their needs, how all its parts are so harmonized that they contribute to their mutual support, and how their action is so unified that they form but one living plant.

To this method of reasoning a writer has answered "that in referring operations to the principle of life, we have not explained them, any more than we have accounted for fire by referring it to the combustible principle." Certainly not; our contention here is not about explaining vital properties or operations, but about accounting for their origin and pointing out the principle from which they proceed. We seek not now to know the intrinsic nature of life, or to define its essential qualities, or to investigate its different stages of development. Our object is simply to show, from the life-signs through the whole vegetable kingdom, that within each plant is a substantial form or a principle of life to which these signs must be traced. Biological phenomena prove, we presume, with as much force, the existence of the principle from which they spring, as any other physical phenomena denote the existence of their cause. External circumstances will indeed modify the development of the plant, but our senses and reason tell us that its growth springs from the innate principle of its life. Through it the character and nature of the plant are defined and a unity given to it according to its determinate species.

Approaching the question from another side, other scientists not only deny that there exists in plants anything like a principle of life, but also assert that vital forces are nothing else than mechanical or chemical forces in an organism, and that as these will produce the heat or the ignition of bodies, so may they also, when properly conditioned, be the cause of vital force,—of life itself. Waiving the point, however, whether mere mechanical force, such as the friction of wood or the hammering on iron produces heat or fire, or whether such force is not to be considered rather as a condition for developing the latent heat or spark, we wish to

examine whether any inorganic force, no matter of what kind, can become by its own nature a vital force in a living organism.

What the bare capacity of inorganic force is in its action on brute-matter, we have seen; all the world knows and admits that it does not originate the least spark or shadow of life, and that howsoever exerted it retains its own material character. This should be received by all as a true test of its nature, and should be taken as clear proof of the fact that whatever vital qualities inorganic force has in a living body it has not of its own. Still a further illustration of this subject, which scientists insist on so much, may be taken from a contrast between a living and a dead organism. Tear up a plant by the roots, it continues to have its organization; mechanical and chemical forces are at work in it; for a time the energies of life also remain in it, but no sooner are these exhausted than its former forces, so far from working for the preservation of the plant, are tearing its tissues to pieces and bringing on its total dissolution. These same forces, while the plant was still living, were its bracing power; they held its parts firmly together and acted on all its fibres to the end that it should be preserved and propagated. All this they did, however, not as inorganic forces, but because they were vitalized; because they received a new influx of force from the vital principle, and in its service became instrumental in building up and fertilizing a living organism. Such is the doctrine which St. Thomas lays down; and such, also, is the doctrine which has been confirmed by the authority of one of the greatest of modern chemists. Speaking of those who maintain that organic life is due only to the chemical combinations of the elements of matter, Professor Liebig says: "They are ignorant then that every chemical combination supposes not one, only, but three causes, since it is always the plastic force of cohesion or crystallization which, together with heat, governs chemical affinity in its productions, and determines the forms of crystals and their properties. But in living bodies there is added a fourth cause, which regulates the force of cohesion, combines the elements of matter to produce new forms and to give them new properties—properties which are not found outside the organism itself."

An effort has been made to neutralize the admission of this great chemist by an argument taken from the analogy that exists between the composition of protoplasm and water. Both resemble each other in this, that they are physical substances; that chemical and physical properties go to form them. Water is composed of oxygen and hydrogen; protoplasm contains carbon, oxygen, hydrogen, and nitrogen. Inasmuch, therefore, as protoplasm and water are composed of physical elements they are alike, although in the number of the elements they are not so; what the agency of the

one is, what its physical qualities are, cannot be predicated of the other. But admitting that under a mere physical point of view they are on a par, under other respects they are essentially different. Living protoplasm is organic, water is not; the former has an assimilating active force, the latter has not; in protoplasm there is the inherent principle of growth, in water there is only a capacity for accretion; on these grounds surely there can be no analogy between them. Water indeed changes into different states; it is convertible into ice or vapor, but no one will seriously hold that ice is formed or vapor generated after the manner in which a plant grows or an animal lives, or that the relation of ice to water is like to that between living protoplasm and dead protoplasm. Life is, therefore, clearly something superadded to chemical elements or inorganic forces and cannot be explained by them. "The differences alluded to," says Dr. Stirling, writing on this subject, "are admitted by those very Germans to whom protoplasm, name and thing, is due. In pronouncing protoplasm capable of active or vital phenomena they do by that refer—they admit also—to an immaterial force, and they ascribe the processes exhibited by protoplasm —in so many words—not to the molecules, but to organization and life."

Men in our time have, indeed, invented machines which, taking up into themselves raw, rough materials, have grappled with them, assorted them, and having digested them, as it were, by difficult processes, have turned them out transformed and refined—quite a new article. And if art can do so much, it is argued, why should not nature do the same, or more, and transmute inorganic forces in organisms into vital vegetative energies? A prompt answer to the question is furnished by the difference of the results in either case. Art, no matter how much it may mix or refine the materials it works, does not change their essential nature; wool or cotton, wrought out into textures the most delicate and the richest, are still essentially the same. It is quite the contrary in the process of living nature. In her laboratory she substantially transmutes inorganic forces, puts new elements into them and bids them perform in the plant functions to which, when not under her control, they are entirely opposed. Besides, that the comparison should hold good, the wool and cotton should be transformed into the machines themselves and not into fine broadcloth. Furthermore, it is to be noted that machinery, however perfect it may be, produces out of elementary materials only stuff composed purely of their nature. Of itself it will insert neither gold tissues in a cotton woof, nor will it embroider a woollen fabric with a silver filigree. Now, in organic bodies, nature, by the law set to it by its Creator, acts differently. Given the same chem-

ical elements and in the same quantity, it constructs out of them bodies of quite opposite qualities and productive of quite contrary effects. Strychnine, for instance, quinine and caffeine are composed of the same quantity of carbon, nitrogen, oxygen, and hydrogen, and still their nature is altogether different. The first is a poison, the second a remedy, and the third a harmless aliment. From this well-ascertained fact Liebig concludes that no chemical analysis suffices to explain the nature of organic combinations; then noting the difference between forces as they exist in and out of an organism, writes thus: "Out of the plant, oxygen constantly manifests its predominant affinity for the combustible elements, carbon and hydrogen; on the contrary, in the plant in which living forces work, oxygen is separated from water and carbonic acid, to be communicated by the leaves to the atmosphere as oxygen. The vital functions of the plant then are all contrary to the process of oxidation which characterizes inorganic nature, they form a process of reduction."

To this teaching, derived from the very constitution of matter and from its law, Mr. Tyndall replies by a sentence which is in the first place based upon a supposition, then on a prejudice, and again on a hypothesis which covers the whole range of possibility. "If then, he says, solar light and heat can be produced by the impact of dead matter, and *if* from the light and heat thus produced we derive the energies which *we have been accustomed to call vital*, it indubitably follows, that vital energy *may have a proximately mechanical* origin." In another passage, however, he speaks of the "mystery and the miracle of vitality."

The process by which the substantial form or the vital principle acts in plants is likened also to the phenomenon of crystallization, in which it has been said, we find "the first gropings of the so-called vital force."

At the close of the last century, the French Catholic priest Haüy was the first to give a clear, definite, mathematical expression to the laws of crystallization. He explained the nature of the force by which crystals are formed, as well as their angles and shape, and how these differ, just as the elements of which they are composed vary. In forming them the crystalline force attracts differently the particles that suit the specific nature of the crystal. In the very bosom of the earth even it has welded ores and metals, in countless varieties of form, while by its inexplicable power it has cemented quartz to quartz and silex to silex with such wonderful solidity that on the granite or rock-crystal might be laid the foundations of the world. It is this same crystalline force that photographs, in mid-winter, frost-ferns on our window-panes, that has moulded and burnished myriads of gems of every hue, and

has given to their structure the greatest variety of proportions. "The splendor of their tints," says an American writer on the Russian jewels, "is delicious intoxication to the eye. The soul of all the fiery roses of Persia lives in their rubies; the freshness of all the velvet sward, whether in Alpine valley or in English lawn, in their emeralds; the bloom of all Southern seas in their sapphires, and the essence of a thousand harvest-moons in their necklaces of pearl."

And wonderful still, crystals attracting fresh matter repair the injuries done to them, they are varied even by adding to or changing some of their elementary particles, they may be classified as it were, into species, and out of fifteen fundamental forms they change their symmetry and structure indefinitely. The formative principle of crystals, however, is essentially different from that of plants and animals. A mere material attractive force, it has no vital function and generates no living tissue. It forms the body of the crystal, not from any germinal principle within it, but by an adhesive power from without it. The growth of crystals is by accretion or by addition of matter to their surface; the growth of plants, on the contrary, is from an internal process, by which the raw material of inorganic matter is transformed and assimilated into the substance of a living organism. In the one case we have a physical law by its cohesive power adding matter to matter; in the other a life-cell, expanding by its plastic force and innate activity into a plant or tree. A lifeless glacier may be formed by the first, but by the second alone is moulded the oak-sapling which, nourished continually by the life-currents shooting through it, shall one day wrestle with the tempest.

Living plants are permeable to water, and are in constant molecular activity under the working of their internal power; crystals, on the other hand, are completely solid and by no internal action either change or modify a single particle of their ingredients. This power, therefore, of growth, from within the plant by assimilation, is the great characteristic of vegetative life. Mysterious in its nature and wonderful in its working, this life develops, nourishes, and fertilizes itself. Puzzled by this mysteriousness and looking back of it, one may be here inclined to ask,—whence originally came this life? has it, in the first instant, generated itself? whence came the first plants and the first trees? To these questions, revelation giving a great lesson to science answers infallibly, God's creative word was the first seed of all living things. "And He (God) said, let the earth bring forth the green herb and such as may seed, and the fruit-tree yielding fruit after its kind, which may have seed in itself upon the earth."

Looking out on the great field of nature with its plants and

flowers and fruits suited to every clime, how little do men think of that silent, never-ending labor with which the vegetative world is manufacturing food for the support of animals. To its formation, earth and air, light and darkness are contributing; the combination of different elements gives it variety and flavor; for its ripening, cells and tissues and fibres are set in motion by a vital principle, and all this through a most delicate and complete woof of mechanism that unerringly works to its end according to specific laws. The clock, the steam-engine, the telegraph, the telephone, by the combination of their parts and forces, flash directly on our minds the intellectual powers of their designers. Their works speak of them. After a similar manner, man, when not biassed by error or passion, can see reflected, in the beauty, variety, order, and productiveness of the universe, God's power and divinity, and in the light of right reason "can look through nature up to nature's God." But could he look behind the rind or bark of plants and study the workings of their interior nature, could he note the functions of the sap—the plant's life-blood, and those of roots and leaves for the plant's sustenance,—he would mark how this incessant activity springs, under suitable conditions, from the vegetative principle of life, and would find additional motives for adoring and praising Him whose wisdom is mirrored in the tiny leaflet or flower as well as in the giant pines or oaks of the forest.

What has been said in the foregoing paragraphs of the life-principle and its formative powers in plants is truer in a higher sense, and for more cogent reasons still, in animals. Both plants and animals have some vital features in common. Existing at first only in germ, they grow in virtue of the activity inherent in their nature; they are distributed alike into different species, possess different members or parts, and propagate themselves according to their kind. But a sensible perception, an internal activity, ruled by sensation, instinct, and appetites, together with an innate, self-moving power,—these animals have, and plants have not. In the latter, life is manifested to us in their growth, in their leaves and flowers and fruit; in animals, life comes out more definitely in their locomotion. To show forth this life-sign, or rather, through it, to fulfil its specific functions, each animal species, from the lowest to the highest, is furnished with a body of a peculiar structure. The jelly-fish, for instance, glides through the water by the pulsations of its own body; the crusty shell of the sea-fan serves it as a propeller; in the star-fish its motor-power lies in the adjustment of its manifold plated covering; while in view of the coming storm the little nautilus freights some of the compartments of its tiny shell and descends for safety to the bottom of the ocean. Mollusks move themselves by dilating or contracting their muscles;

insects innumerable, with jointed legs and with wings firm or web-like, "with a nervous system encased in a single internal cavity," signal forth life by different degrees of swiftness. In the vertebrates, the organs of locomotion are more perfect and varied than in other animal species, and may be classified in some respects, it has been said, under the same laws of structure. Through the whole animal kingdom, however, as the most cursory observation shows, life is manifested in different grades, by different species and classes of animals. In one form it is seen in that power, by which, at its pleasure, the oyster opens or closes its shell, or in that by which the structureless amœba contracts itself; and in another form, in that agility with which the eagle sails in mid-air, or in that with which the stag bounds through the forest. But by locomotion of one kind or another, life displays itself in all animals, from the animalcule that dances in the sunbeam, to "the great finner whale," that disports in Northern seas, "his eighty or ninety feet of bone, muscle, and blubber."

Besides this self-moving power which animals possess, there are going on within them the unceasing functions of vital activity, the development of their form and organs, and the assimilation of food to their specific qualities and wants. Similar operations, we have seen, are going on in plants under the organizing law of a vital principle. Under a like principle also, but of a higher and different nature, animals live and move. The plant's living activity is determined for it by physical law; it specifies for itself, by no immanent act whatever, the manner of its living or the nature and qualities of its food. Its sole function is to put in execution the uniform law of activity and fruitfulness prescribed to it by its Creator. In the irrational animal the case is otherwise. The principle of its life, or its immaterial sensible soul, originates the law of its sensible activity. Through its senses it is brought into relationship with myriads of sensible objects; it sees or hears, scents or tastes or feels them, and forthwith by its sentient faculty it has a perception of the sensation that affects it, or of the image that sense mirrors to it. It is not the mere physical impression, however, that moves the animal, or stirs it to action, but the actual perception of the sensation; a horse, for instance, may look at an object for hours and may not realize its presence; the steady fixed gaze rivets its eye, but it is only the force of attention that gives it the living power of vision. How indefinitely varied then, how continual and vivid is the activity of the animal, we may gather from the countless ways in which objects touch its senses. Emotions of pleasure or pain, of fear or hope or joy, affect it; and by them it is inexorably ruled. It cannot break with its instincts, and is inevitably drawn to satisfy them; it has neither the freedom of

choice of the means to gain its end, nor has it free volition wherewith to curb its appetites. The activity of the brute then is limited by its instincts. Its soul generated with its body is essentially dependent on the same; it cannot rise above its sensibility into the high sphere of speculative or intellectual life; it has no "mental sight," no "contemplation of mental operations or results as opposed to experience, experiment, or sense," nor can it go behind the mere sensible qualities of physical objects to form those universal ideas that represent the characteristics of a species. A dog recognizes his master but has no idea of humanity.

Still even with these limitations the brute possesses wonderful vital activity; through its senses and imagination, impressions of every kind flow in upon it, and when seized on by its soul become its motor-power. But besides those impressions which are derived from its sensibility, there are different vital operations in its vegetative nature, all controlled by its sentient soul. Under its vital influence the brute assimilates food to its substance, forms bone and muscle from mineral and liquid elements, and by the balancing of the matter of waste against that of repair is continually renewing the material of which its body is composed. Of these and other operations of its vegetative nature, the brute has no perception, although they are dependent on the principle of its sensible life—its soul. It is this which makes the animal's vegetative nature to have features different from those which it has in plants. In these it works out its special ends according to the laws assigned to it, without dependence on any other natural superior force. In the irrational animal, on the other hand, that vegetative life is dependent on a superior organizing power; it is made to minister to a higher nature, is vitalized by it, and forms with it one complete living substance. From the sensitive soul, therefore, of the animal, as from a principle of vital force or a substantial form, spring those influences that touch and energize all the powers of its nature; from it comes those life elements which change and elevate with new vigor the forces of its vegetative life, and which puts into its senses those vibratory faculties that bring it into intimate contact with the external world. These are facts which we can partly realize for ourselves by looking down into the vegetative and sensitive nature of our own bodies; and yet these facts so-called science has sometimes endeavored to falsify.

About three centuries ago, Descartes, following the views of the Spaniard, Gomez Pereira, maintained that all brutes are only *automata*, which are moved by some mechanical contrivance, although they seem to move themselves. Descartes, however, admitted that animals possessed a lower kind of soul, but this, he taught, is to their bodies much what steam is to the iron framework of an en-

gine. This theory, strange to say, has been maintained by some modern scientists. To them, animals are no more than machines, though the plan on which they are modelled is altogether a peculiar one.

After having stated this view, many modern writers pass it over without deigning to refute it; its very extravagance they consider to be its best refutation. It has been pronounced false by the judgment of the human race, and consequently by the law of right reason. It stands not the test of experience, and is at variance with what men know of animal life. A machine, understood in any legitimate sense of the word, receives from an agency without it its strength and activity; it neither makes nor repairs itself. But the animal grows in virtue of its soul—the inherent vital principle of its nature; it makes and sustains itself by assimilating food according to its wants, and by the quickening energies that run through it. Without any extrinsic cause whatever the innate vital power given to it by God's creative word adjusts its organization for the place it is to have in the animal kingdom. In the abstract, the animal's soul may be considered apart from its body, but in its actual living state the animal is not made up of two independent agents, as it were, welded together, but is one living creature, which is the subject of various emotions.

Many years before Descartes's time another theory on brute-life was put forward by Chancellor Bacon, of England, the extravagance of which, though perhaps less striking than that of which mention has just been made, was not less real. The soul of the brute he considered to be material; to be "a fine commixture of flame and aerial substance," an opinion which had been upheld many centuries before by some pagan Grecian philosophers. The Chancellor, taken up with the study of physical nature, and desirous to ennoble it as much as possible, sought to give to the phenomena of the animal's soul a material cause. All the while, however, he forgot that there can be no relationship between them, since the most imperfect knowledge like that of the brute is engendered by the act of perceiving—by the apprehension of the sensible form of the object by the sensitive soul. Matter, as its nature teaches us, however subtile it may be supposed, can never gather up into itself the living image of any given object, then identify that image, as it were, with itself, and from their union form anything like knowledge. Stamp or impress matter as you may it will never produce anything but matter. Let it be an atom, or a fluid, or a chemical agent, or a vitalized mechanical force, all the same, everybody admits that it is incapable of knowing, because it is incapable of perceiving. Life even does not correlate thought no more than matter correlates life. A tree does not think although it lives; neither does

a stone live because it is matter. But the barest outlines of knowledge connote the immanent acts of a perceptive faculty, of an immaterial, though sensible, principle, such as the soul of the brute. It alone can take in, separately, the sensible forms of the numberless objects that fall beneath its senses, can picture each object to itself, and feel the impulses of life from instincts and appetites.

On this subject of brute-life it is singular to note, how controversy has run counter to itself. In the seventeenth century scientists were zealous for even degrading the brute by reducing it to the level of a mere machine; in our days, on the contrary, scientists strive to exalt the brute by pretending to make it a man. Then, whatever they may have taught about brute-life or capacity, they always recognized the transcendent superiority of man's reason; now, they would ignore man's reason, and if they could, would make the brute rational. This admiration for the brute creation has entered even into the working of civil life, and there is formed a "Society for the Prevention of Cruelty to Animals," which writes beneath the statue of a horse, "justice, humanity, compassion." The horse is to be decently kept and comfortably lodged; meanwhile man is often left to shiver and hunger in the cold, or to be sheltered in houses, some of which, for order and cleanliness, we have been told by the press, are not to be compared with many stables. It is indeed a good thing to prevent cruelty under any form, but surely it ought to be one of man's first cares to alleviate the hardships and to provide for the needs of his fellow-men.

Sympathy for suffering and abhorrence for cruelty are the grounds on which some persons, nowadays, protect brute-life; others, however, would do the same, but on the plea that man and the brute are of the same lineage. A few years ago, this latter view made some noise and excited curiosity; it was not precisely new, but it was presented in a new form. For a few seasons, it had a "run," and put into bookshape, was as marketable as a sentimental novel. But when able scientists came to grapple with it, they found that it began with conjecture and ended with conjecture, that some of the facts on which it rests were of doubtful existence or of doubtful meaning, and that when other data were wanted, they had to be supplied by fancy. In a word they found that there is no real science in Darwinism.

The great law on which this system professes to rest is that of verification; and judged by this law the system has completely broken down. The antiquities of the ancient kingdom of the Pharaohs bear testimony against it. During Napoleon's campaign in Egypt animal and vegetable fossils were discovered there that date back, it has been estimated, some six thousand years; and these fossils have been recognized by all naturalists as being exactly of the

same kind as the animals and plants of the Egypt of to-day. A more striking refutation still of this theory of "the transformation of the species" is taken from the coral reefs on the coast of Florida. The formation of these, some geologist tell us, spans ten thousand years, others say twenty thousand. Now the coral insects and the shell-fish which have built up these reefs, at least in part, are just, in their specific nature, in the lowest stratum, what they are in the highest. Indeed in all the geological formations, from the Cambrian bed to the earth's surface, there have been found fossil remains of plant and animal species, some of which are extinct, while others exist at the present day. In each of these strata fossils of the simplest structure are mixed with those of a more complex nature; but in no geological formation have fossils been discovered to mark the transition of one species to another,—of the zoophytes to the mollusks, of the mollusks to the articulates, of the articulates to the vertebrates. Mr. Darwin himself acknowledges that there are no data wherewith to prove these transitions, and then, in spite of the obstacles put by hybridism to his system, he and his followers come into court, so to say, promising to prove their case from "geological documents," and when challenged to produce them, fall back for proof, without any fear of paradox, on the want of documents. Making all due allowance then for the "scientific use of the imagination," it is difficult to comprehend how a physical theory which rests on no positive proof can claim to be scientific. The great instrument of this theory is the modification of animal organs or members, but surely experience teaches, that such modification, even when it is hereditary, does not change the species. There are numberless varieties among plants and animals, but their species remain the same. The change of a species, if it were to take place at all, should come from the life-principle that organizes its individual members and gives them their distinctive characteristics. If the transformation of one species into another were one of the natural functions of this principle it should always work to its end in spite of any accidents of modifications. Still, Mr. Darwin holds, that after a time species become immutable and that the law of evolution comes to a stoppage. He will not have it go farther than he wants, and as it would seem, will dictate to nature when it suits him. "No ordinary matter known to us," says Dr. Lionel S. Beale, "does such wonderful things or acts in any way like the matter which is supposed to be always developing variations to be instantly taken advantage of by selection called natural."

Under the application of this system to the human race man is only an outcome of the freaks of animal nature through the agency of "natural selection." His lineage, however, in this hypothesis,

cannot be proved; the record of his descent is entirely missing, since it cannot be found among the fossils of the dead past, nor among the living animal races of the present. On scientific grounds, indeed, the hypothesis has been rejected by the leading scientists of the day, and a place apart has been assigned by them to man in the animal kingdom.

"In the name of scientific truth," says M. de Quatrefages, "I can affirm that we have had for ancestor, neither a gorilla nor an orang-outang nor a chimpanzee, any more than a seal or a fish or any animal whatever" (*l'Unité de l'Espèce humaine*). Even scientists of the school of Mr. Darwin, considering man only from the point of view of anatomy, admit that his erect stature, the adaptation of his feet for walking, the development of his brain put him at an immeasurable distance above all other animals. This was exactly the doctrine which St. Thomas taught some six hundred years ago, and for which he gave his reasons. "Whereas other animals," he says, "are delighted with the sensible only, to satisfy their hunger or other sensual appetites, man alone delights in the very beauty itself of the sensible creation. And whereas the face is the principal seat of the senses, animals have their faces turned toward the earth as if in search of food, but man holds his face erect, that by his senses, especially by his sight, the most subtile and most discerning of all, he might freely know, everywhere, sensible phenomena, both heavenly and terrestrial, and from all gather intelligible truth." "Among all animals, man ought to have, relatively to his body, the largest brain, in order that in it might take place more freely the operations of those interior sensitive forces which are necessary for the action of the intellect."—Summ. 97, 1 p. qu. 91, art. 3.

In maintaining the hypothesis of evolution scientists lay great stress, sometimes, on the phenomena of embryonic life. It points, they think, directly to an affinity between the species and to the facility with which they may have been transformed. All animals, observation has shown, are oviparous, and in embryo undergo various changes before they are "differentiated" and receive their specific organization. In the ovules they seem to be akin, but when they have put on severally the shape and dress of their species and their life history begins, they disclaim relationship with those of different specific organizations. On this subject, German physicists, particularly, have rung the changes. Of it, Büchner writes: "Embryology gives us a formal and irrefragable testimony in favor of the intimate parentage of all living things;" while Haeckel, following up the same line of argument, stigmatizes those who differ with him as "superstitious," and as "ignoramuses." In common with these writers, Mr. Darwin upholds the same view,

but in a tone far less arbitrary and dogmatic. "The embryos of a man, dog, seal, etc.," he says, "can at first *hardly* be distinguished from each other." Even Büchner and Haeckel, on second thought, retract, virtually, what they so boastingly asserted. The former writes: "After all it is certain that there are differences between the ovules and the embryos—differences precise and characteristic. But these do not exist in the outward forms, though, to confess the truth, even in these there ought to be some diversity, but too minute to be verified by our optical instruments. The differences of which I speak ought to exist in the intimate constitution and in the chemical and molecular composition."—*Man, according to the Results of Science.* The latter (Haeckel) speaks thus: "The subtile differences of each ovule,—as being indirect and virtual,—cannot be directly ascertained with our means of investigation. Still, by natural induction, they ought to be admitted and recognized as forming the first cause of all the individual differences."—*History of Creation.*

This self-contradiction illustrates a phase of much of what is called modern science. It boldly asserts, then, when asked to prove, shifts its ground, and again when pressed to answer, pulls down the work it strove to raise, by sapping its very foundation. The ovules of various species are *hardly* distinguishable, but still they are distinguishable; they seem to be altogether alike, but they are not. Their formative force it is which forms the rudiments of the organs in the embryo, and thus by degrees, through the influence of life, species are distinctly separated from species; varieties are formed even within these species, and the brute creation, with its distinctive characteristics, lives and grows in virtue of the organizing, sensitive soul of each of its members. For the developing of the phenomena of embryonic life, heat and other external circumstances, are required. In order that the plastic force of the ovule should exercise its functions, it must be properly conditioned; by a general law of nature it needs external aids for the process by which it works on towards its end, and as in the case of all human and natural agents, external conditions form the apparatus through which it acts. But conditions are not causes, nor are embryonic phenomena the effects of any external circumstances. "If these phenomena are to be regarded as consequences of heat we may as well maintain that a steam-engine is a consequence of the coal that takes part in generating the steam that turns the lathes that are used in its construction. All the force, all the heat, all the motion of the non-living universe is incompetent to develop a living monad, and this the physicists know."—*Protoplasm, or Matter and Life*, by Dr. Lionel S. Beale.

The theory of physical life, however, that offered the most prom-

ising field to the advanced school of scientists, was that of "spontaneous generation." It had a long history; three centuries before Christ, its first principle was formulated by Epicurus in these words: "The earth is the common mother of all that lives, and from that origin so simple man himself is not exempted." Modern Epicureans do not state their views so plainly as their master, but when analyzed, these views are strictly reducible to his principle. As far as the production of some lower organisms was concerned, this theory had some grave mediæval authorities quoted in its favor. By them, of course, the thought was never entertained that matter possessed in itself "the potency of every form of life," but it was a great deal for the school just mentioned to have it admitted that matter could produce life at all. For some years Haeckel and other physicists were enthusiastic on the subject; they pretended that in the formless particles of albumen they discovered inchoate life. As a test-proof of what they said, they quoted Bathybius, an organism which, they averred, sprung to life spontaneously in the bottom of the ocean. Much talk was held about the matter at the time, and spontaneous generation was in the ascendant. Well, Bathybius was put to the crucial test of chemistry, and was found and admitted to be nothing but the sulphate of lime. This theory has now completely broken down, and this delusion of scientists has been dissolved by modern experiments. M. Flourens, a member of the French Academy of Science, thus writes on the subject: "Since Redi (1668) no one maintains the spontaneous generation of insects; that of intestinal worms has no longer a serious advocate since Van Beneden (1853); since Balbini, the origin of infusoria through spontaneous generation has been abandoned; and after the experiments of M. Pasteur (1865) it has been generally given up in regard to all kinds of animalcules." In 1875, the last-named scientist, after having confirmed his first discovery by successive experiments, thus addressed his audience: "Oh, behold, then, far from us and relegated to the region of chimeras, all the theories of fermentation imagined by Berzelius, Mitscherlich, Liebig. . . . . All this scaffolding created by the imagination has given way before our experiment, so simple and still so searching."

In the phenomena of the vegetative and animal kingdoms man may study the characteristics of physical life, but it is in himself that he becomes intimately acquainted with them. In living objects around him he studies life in its outward forms; in himself he perceives what it is by the consciousness of his vital actions; he sees it, as it were, face to face. By doubling his thought on itself he is conscious of his power of thought and of motion, and through his intellectual acts he is aware of the principle of his ex-

istence and vitality. "This," says St. Thomas, "every one experiences in himself, that he has a soul and that it vivifies."—*De anima.* "Man perceives that he has an intellectual soul, from the fact that he perceives that he understands."—*Summa*, p. 1, qu. 87, ar. 1. All man's natural knowledge must be of his own making, and the preliminaries of that knowledge must come through his senses, or imagination, or his sensible memory. He has no innate idea either of God, or of nature, or of life, or of anything whatever, and for the arousing, as it were, of his intellect to action he depends on sensible impressions. These or the images of sensible things are taken and vitalized by the inherent power of the senses; they are the excitants of thought, the phantasmata, as they are called, over which the intellect casts its own pure light, looks through their sensible character, in order to find beneath them its own object,—the intelligible. Man knows that he knows; is conscious of what worth his knowledge is; the brute is not; the latter's soul is restricted in its perfectibility by nature; the former's intellectual faculties may be more and more perfected. "Other beings are complete from their first existence in that line of excellence which is allotted to them; but man begins with nothing realized (to use the word), and he has to make capital for himself by the exercise of those faculties which are his natural inheritance. . . . . It is his gift to be creator of his own sufficiency, and to be emphatically self-made." The sensible form of things is the object of the brute's soul; the supersensible, the substantial form or the real truth of things is the object of the intellect of man. Its aliment, so to say, is being, essence, nature, substance, etc., which are common to all things; or animality, vegetation, heat, cold, humanity, and other such properties which may be predicated of specific classes of creatures. By its searching, abstractive force the human intellect breaks through the barriers of thought, widens more and more its view of particular objects, and by seizing in them what is universal by nature, reaches those ideas which are based on the essence of things. "The intellect," says the author just quoted, "knows directly, only the universal; indirectly, and as if by reflection, it can know the singular."—*Summa*, p. 1, q. 86, ar. 1.

In the very depths of man's nature then, within the very sanctuary of his soul, there is going on a far-reaching activity that reveals him to himself and teaches him that his soul has come from God's creative power and not from human generation. In its distinct mental operations his intellect breaks loose from the senses, acts above and beyond them, searches into the depths of God's being, looks back into the soul through its own thoughts, examines justice, goodness, honesty, duty, compares idea with idea, and projects its thoughts even unto infinity.

Not only in this great reach of the mind is man's natural activity displayed, but in a more striking manner still, in the freedom of his will. Howsoever far the mind may penetrate by its native energy, thither the human will can also lead by the force of its desires. The aim of the first is truth, the aim of the second is happiness. The intellect is by its nature necessarily determined to its end; the will, on the other hand, though naturally inclined to seek for happiness under some indeterminate form, is free to look for it in this or that object, and to strive to acquire it by this or that means. Herein lies one of the great characteristics of man's rational nature. When his desires are rushing to their object with more than the velocity of lightning, he can put a brake on them by his will-power; of two objects he can choose the least pleasing to him, or reject both; and even by the abuse of his freedom of will he can swing himself away from the observance of the moral law and from his obligations to God. In these and a thousand other ways the conscience of every one tells him that he is a free agent, the master of his own acts, that for these he is accountable to his Creator, who has prescribed to men duties as well as rights.

The few reflections just made show, I presume, that the activity of the human soul is indefinitely greater and of an incomparably higher order than that of any other creature in the animal kingdom. The soul is the substantial form, the principle of life of the body, and both united in man form, not two substances but one substance,—one individual human being. In him is vegetative and sensitive life; in his body are combined the vegetative functions and the sensitive faculties of the animal. Into the bearing of these functions and faculties he can look from the height of his intellectual power, feel their energy and scope, and thus through his own consciousness, get the knowledge necessary for the interpretation of the inner life and resources of both the vegetable and animal creation. Outside man, vegetative and sensitive natures are formed and sustained by their respective principles of life, as their substantial forms; in man, these same principles are taken up into and virtually contained in his intellectual soul. What they did in the plant and animal, that the human soul in a higher order and for its own special ends does in man. It energizes the vegetative and animal elements of his nature, gives life to every nerve and muscle and cell and tissue of his body, and makes it to be a human body. This body, the soul by its influence and presence informs and so governs, that in man there exists, in the specific sense, but one nature,—the human. The body grows, but the soul does not; as it comes from the hands of God and is united to the body, it is complete in all its faculties, but, for the proper exercise of them,

needs that the body should be fully organized. How marvellous for this end is the life-power in man science teaches us.

"At the threshold of life," says one of our modern textbooks, "the wisest physiologist reverently admires, wonders, and worships. How strange is this transformation of food to flesh! We make a meal of meat, vegetable, and drink, ground by the teeth, mixed by the stomach, dissolved by the digestive fluids; it is swept through the body. Within the cells of the tissues it is transformed into the soft sensitive brain or the hard callous bone; into briny tears, or bland saliva, or acrid perspiration; bile for digestion, oil for the hair, nails for the fingers, and flesh for the cheek. Within is an almighty architect who superintends a thousand builders, which make, in a way past all human comprehension, here a fibre of a muscle, there a filament of a nerve, here constructing a bone, there uniting a tendon, fashioning each with scrupulous care and unerring nicety. So without sound of builder or stroke of hammer goes up day by day the body—the glorious temple of the soul."

In this building up of the human body by means of these vital energies which the soul imparts to it, we may readily understand how great must be the activity of man's internal physical life; and how wonderfully active his external life also is we may learn from the histories of individuals and nations. They give us the summary of man's vital power in its physical, moral, and intellectual character. In them we may trace the mingling, so to say, of the thoughts and views of men, the contact of actions with actions, and of interests with interests, the tendency to a common end by legitimate means, or the formation of those bonds which constitute social life. This manifestation of life, however, varies with the religious, moral, and intellectual culture of tribes and nations; and even in physical features, races differ from each other. But these differences, no matter how great, do not break up the unity of the human species, nor imply that all men have not descended from the one common father. It is universally admitted that certain tribes or classes of men degenerated, fell away from the primeval type of manhood, but for all that they did not cease to be men. Amid the wreck of many of their natural or acquired powers, their rational nature survived; they had still left to them some sense of religious worship, some perception of good and evil, of right and duty. At the hands of certain scientists, however, savages fare badly in our time; they are made worse than they really are in order to better, if possible, wild theories, and are supposed to have come from ancestors more degraded than themselves,—ancestors not superior in fact to the brute creation. These prejudices, however, have partly ceased to exist, and the character of savage tribes is now better appreciated. How guileless and simple that character was a few centuries

ago in the case of many tribes we learn from the narratives of the discoverers of this continent. By recent explorers, savages wherever met with have been recognized as possessing the characteristics of humanity, while antiquarian research has proved conclusively that savagery was not the primitive condition of mankind. As far back as the oldest records go, and that is to the cradle of the human race, civilization is met with. In many respects undoubtedly it differed from what is now defined to be civilization; it did not run mainly on the lines of physical comfort or of great wealth, but embraced at least two essential elements of all true civilization, namely, religion and morality. From this ideal of the conduct of life many tribes fell through their own excesses, and considering the inclination of human nature to evil, their descent was an easy one; but on the other hand, all history is there to tell us that ascent from the savage state to civilization is very difficult; nay, facts go to show that a savage race has never yet risen as a race to the fulness and elevation of a truly civilized life.

The physical features of men, natural history teaches, will also be modified by their environment. Climate, food, customs, moral habits act forcibly on the human frame and contribute to form diversity of races but not diversity of species. Formerly, the striking contrasts that exist between the different races of the human family, were the grounds on which scientists argued against its unity. But, as Alexander von Humboldt remarks, "Most of these contrasts have vanished before the profound studies of Tiedeman on the brain of the negro, of Vrolick and Weber on the form of the pelvis, and of Flourens on the human skin." To the same conclusion linguistic studies have led many scholars. Having gone back through languages, analyzing and comparing them, they have been able to reduce them to three great parent-tongues,—those spoken, they say, by the descendants of the sons of Noe,—and farther back still, under the structure of these same tongues, Leibnitz and other linguists have found the remains of one primitive, original language, of which it was written, "And the earth was of one tongue and of the same speech."

Indeed the human family itself by the laws of its generation proclaims its unity. Hybridism, it has been unmistakably proved by naturalists, is not in the order of nature. Every species of plant or animal, in order to propagate itself indefinitely, must remain within its own limits. If in some instances, different (although proximate) species have been prolific, this at most has been only for two or three generations. After that time there is a reversal of the breed to one or other of the primitive stocks, and the species again maintains its exclusiveness, and with its varieties or races wants to live for itself. It marks out its own boundaries; outside

these its union is a forced and unnatural one, within them the fact that its races are prolific is a proof that they are of the same specific nature. This lesson derived from the vegetable and animal world has set forth in a clear light the unity of the human species. Human races intermarry, and because they are of the same original human stock, there is no limit put by nature to the generations of their descendants. Under whatever climate they may be, or under whatever circumstances, be these the most degrading, they are recognized as having the essential attributes of humanity. The contrary opinion has now become almost obsolete. Differ widely as modern scientists do about the origin of man, they generally agree in regard to the unity of the human species. Still by proving the unity of man's nature, one has gone far to prove the unity of his origin. If, as naturalists admit, among inferior animals "a new race can readily be formed from a single pair," it may be easily conceived how the first race of men sprung from Adam and Eve, and how from it other races were formed by some variations, which in time became hereditary. This stray truth, so to speak, acknowledged by antichristian scientists of our day was also uppermost in the minds of pagan nations of the remotest antiquity. Obscured by fable, it lost for them its full meaning, but read in the light of true tradition and philology it teaches us that from the beginning mankind were acquainted with the real history of their origin. Thus it has come to pass that in this respect and in many other ways, real science has been the handmaid of faith, and after having been confused by theories on man's origin finds the inspired record of Moses to be the only firm ground on which it can securely rest. And He (God) said: "Let us make man to our image and likeness; and let him have dominion over the fishes of the sea, and the fowls of the air, and the beasts and the whole earth and every creeping creature that moveth on the earth. And God created man to his own image, to the image of God he created him, male and female he created them."